Top Quark Properties at the Tevatron

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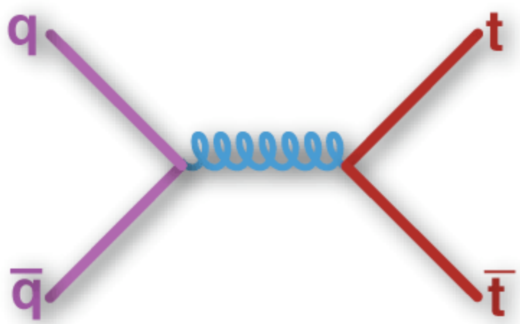
For the CDF and D∅ Collaborations

How is Top Produced at the Tevatron?

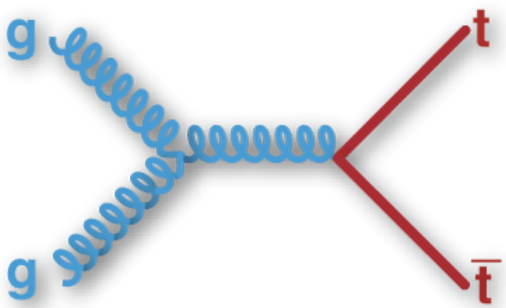
Strongly

- Large theoretical uncertainties
- As QCD predicts?
- Only SM top?
- By heavy particles?

~85%



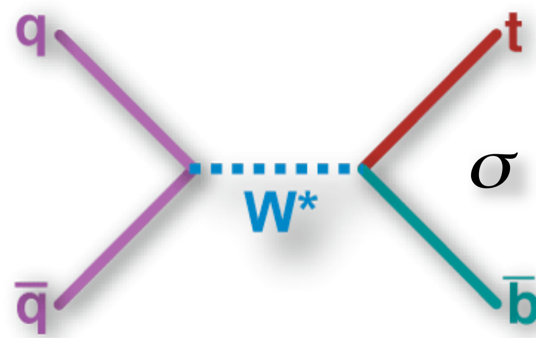
~15%



$$\sigma(\bar{p}p \rightarrow t\bar{t} \,@\, M_{top} = 175 GeV) \approx 6.7 \text{ pb}$$

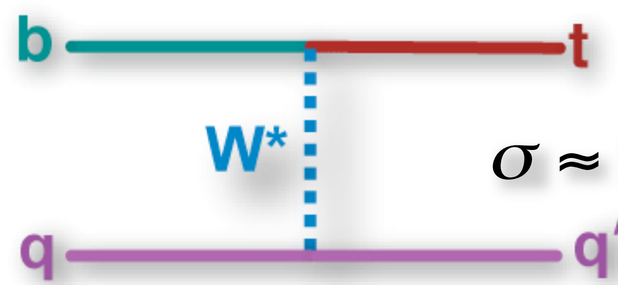
Weakly

- Rate $\propto |V_{tb}|^2$ in SM
- Sensitive to H^+, 4^{th} gen, W′, FCNC, ...
- Signature ~ SM Higgs



$\sigma \approx 1$ pb

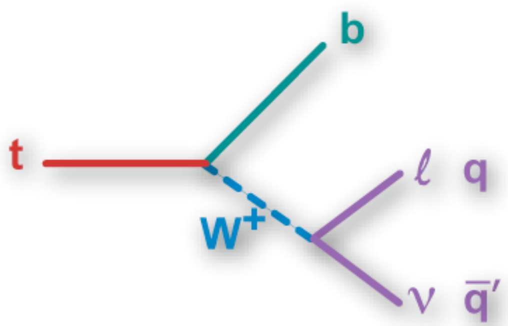
s-channel

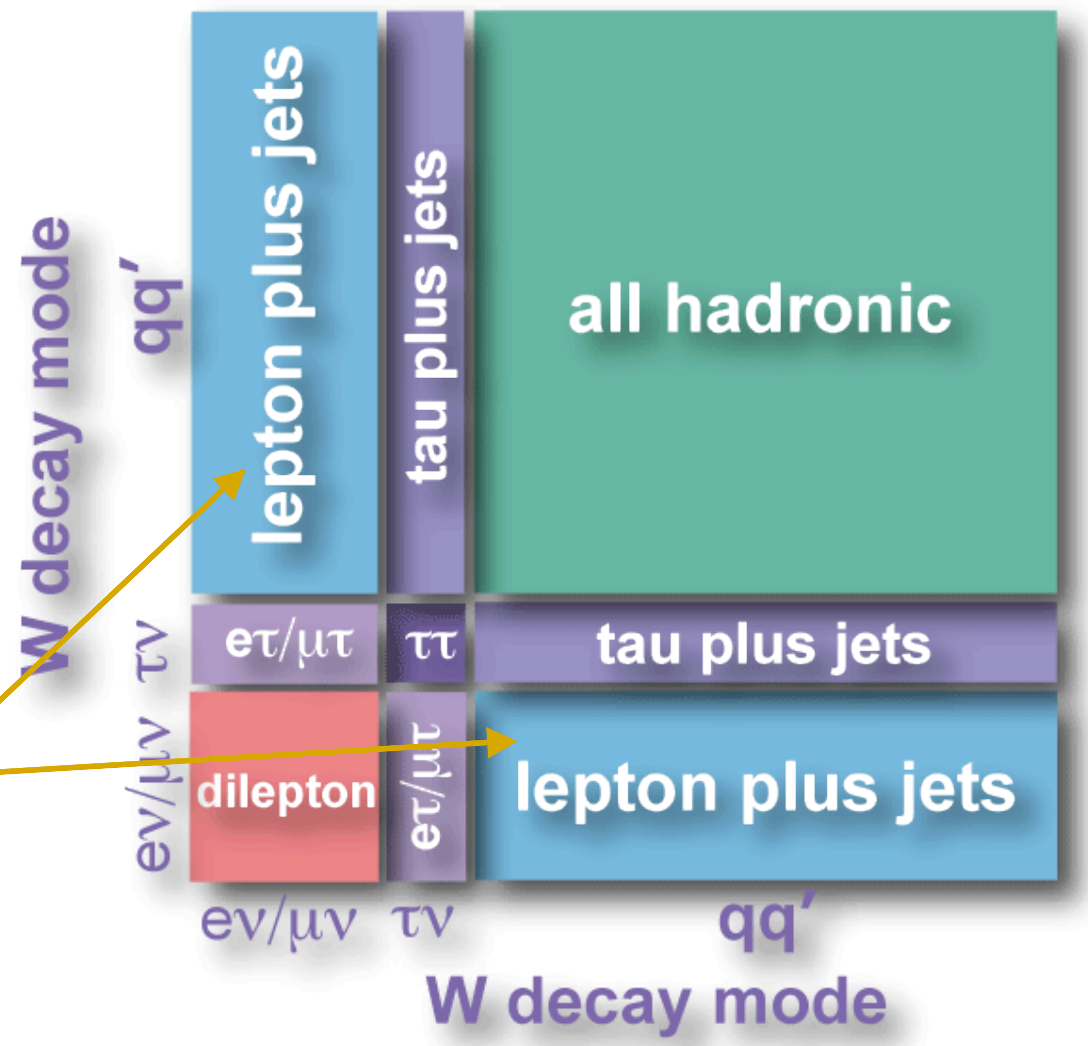


$\sigma \approx 2$ pb

t-channel

How Does Top Decay?

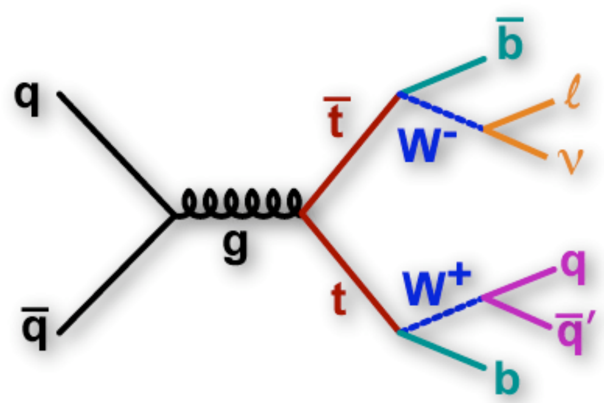


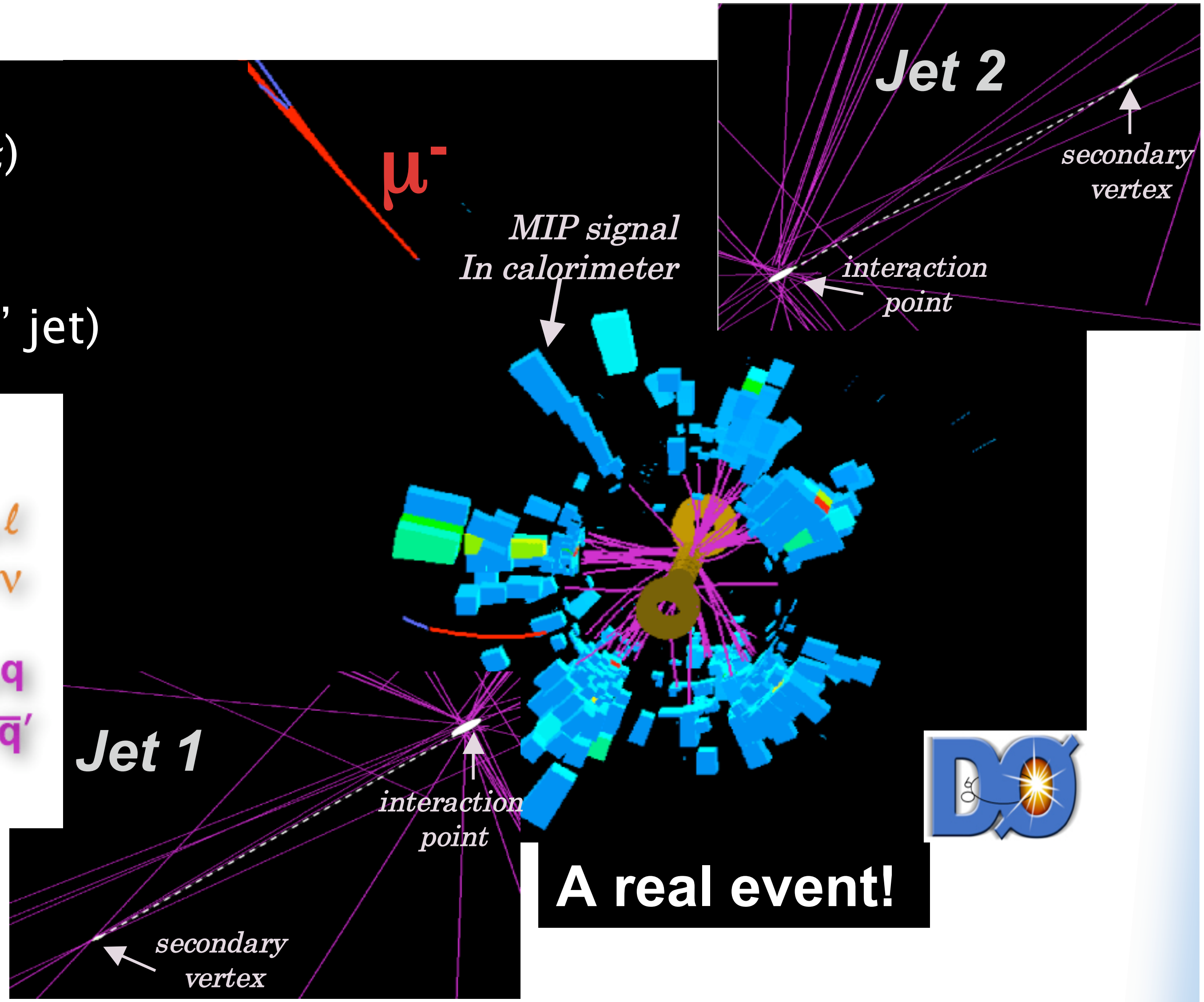


lepton +jets is the "golden channel"

Identifying Top

leptons (e,μ and τ)
ν (missing E_T)
quarks (jets)
b-quarks (“b-tag” jet)

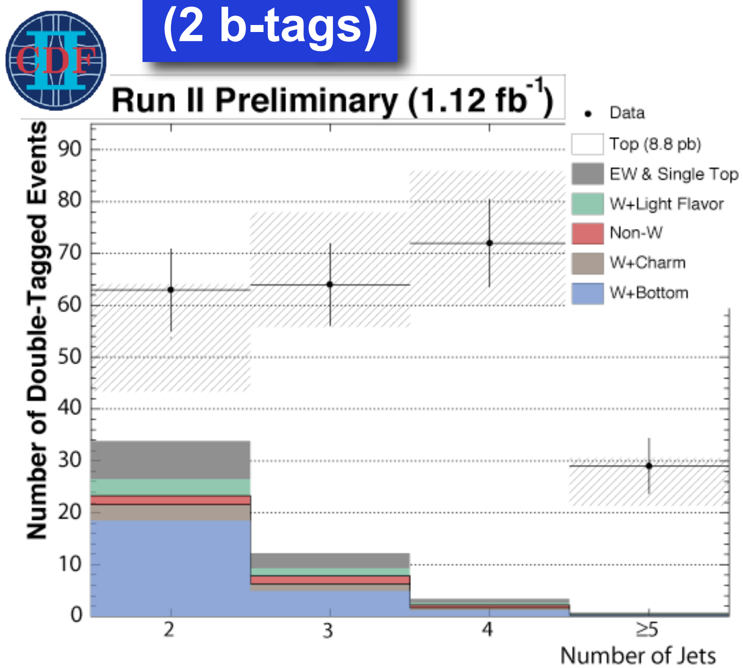


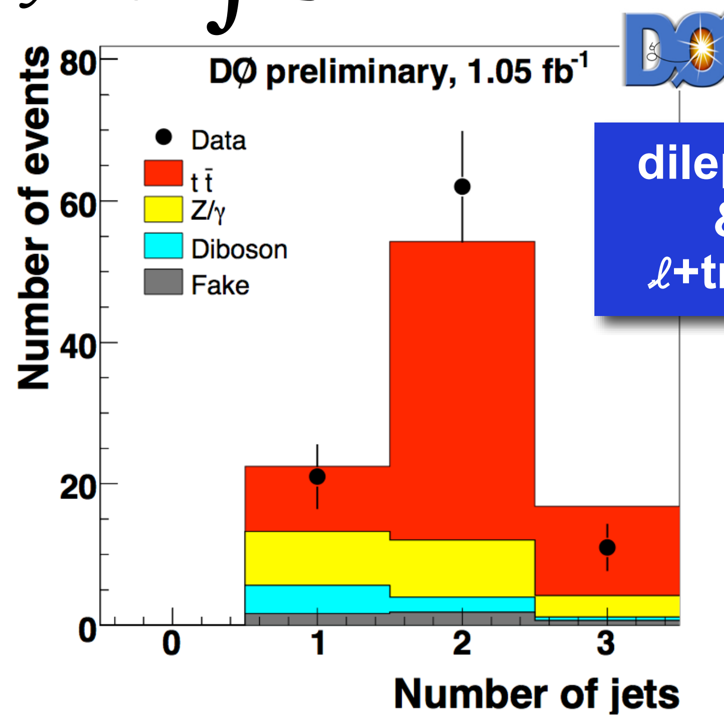


Top Pair Cross Section

$$\sigma(p\bar{p} \to t\bar{t}) = \frac{N_{obs} - N_{bkg}}{\mathcal{A} \cdot \varepsilon \cdot \int \mathcal{L}}$$

ℓ+jets
(2 b-tags)





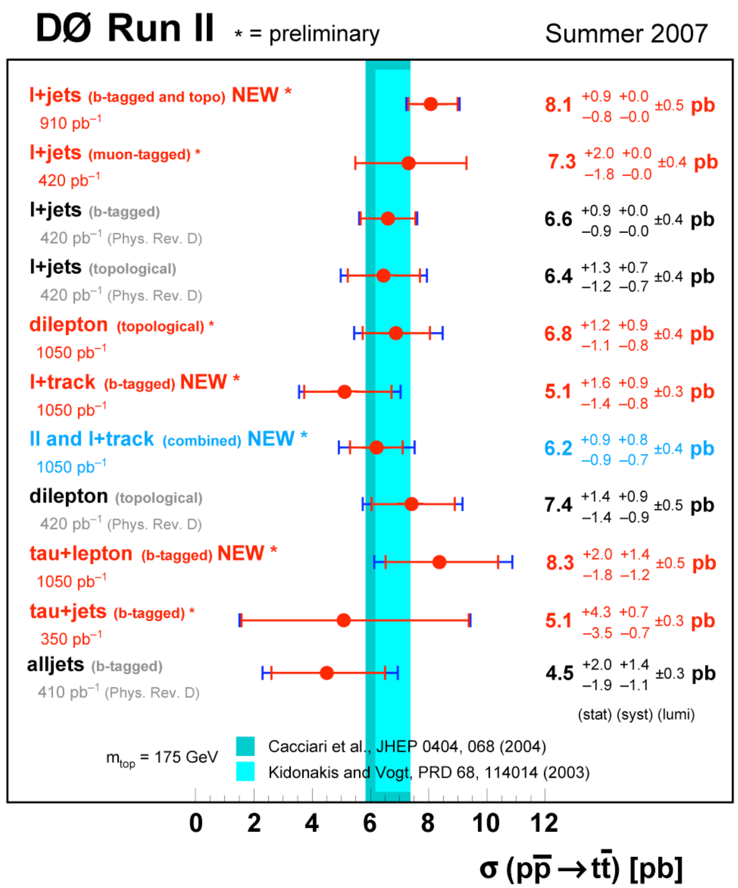
dilepton
&
ℓ+track

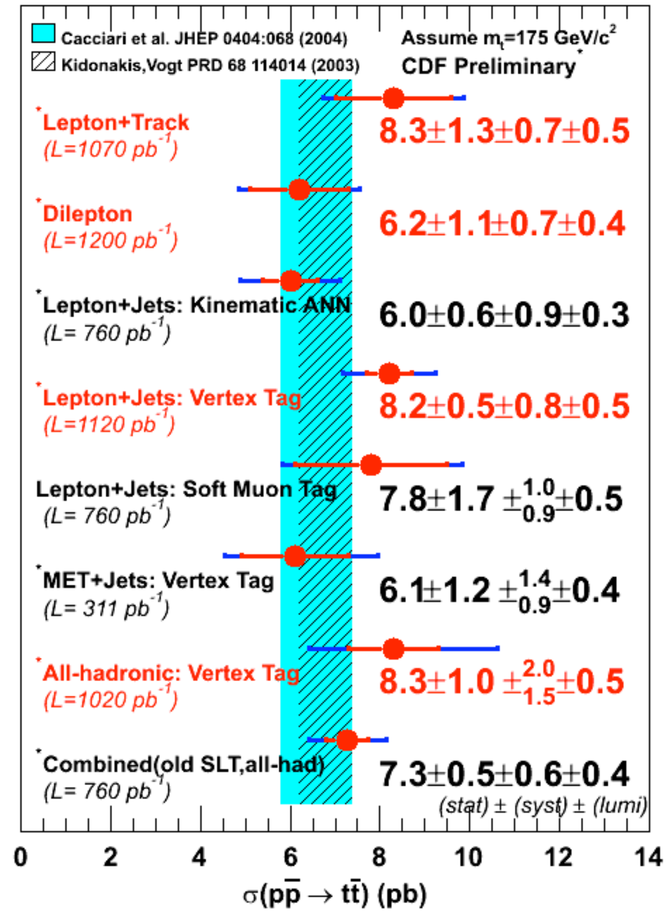
For example, in ~1 fb^{-1} of integrated luminosity:

~60	dilepton	S/B ~ 2-3:1
~200	lepton + jets (with b-tag)	S/B ~ 3:1
~300	all-hadronic (with b-tag)	S/B ~ 1:5

Main backgrounds
-W+jets, WW, WZ, DY
-mistag, W+hf, V V, non-W
-QCD multijets

Summary of Top Pairs Cross Sections





Measurements in all channels using different methods are found to be consistent

Good agreement with SM prediction

Sample composition well understood → use it to look for new physics!

Single Top Production

Very rare! First evidence of single top production! Working towards observation.

Use many different techniques to extract signal from large backgrounds

Multivariate techniques: boosted decision trees, matrix element reconstruction, bayesian neural networks, likelihood discriminants

Matrix Element Techniques

Also see talk by R. Demina

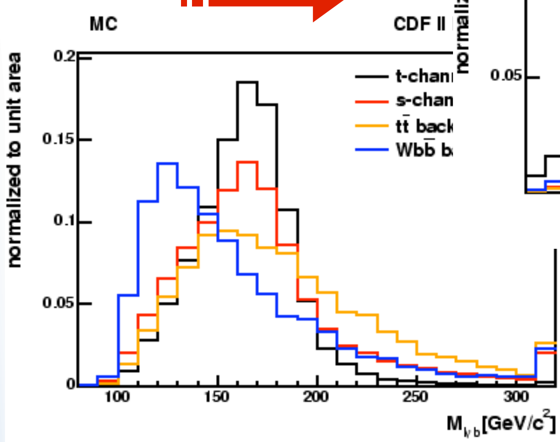
dσ **is the differential cross section (Matrix Element)**

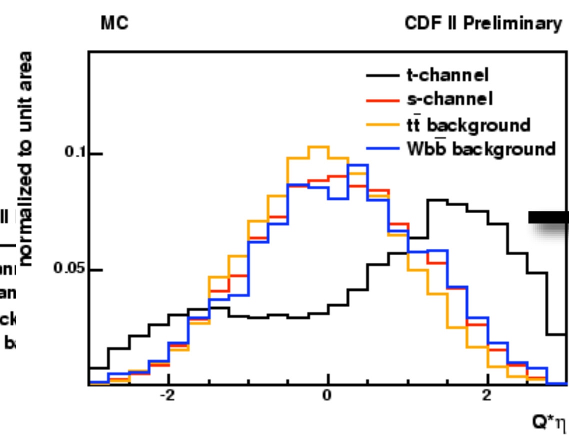
W(x,y) **is the probability that a parton level set of variables *y* will be measured as a set of variables *x* (parton level corrections)**

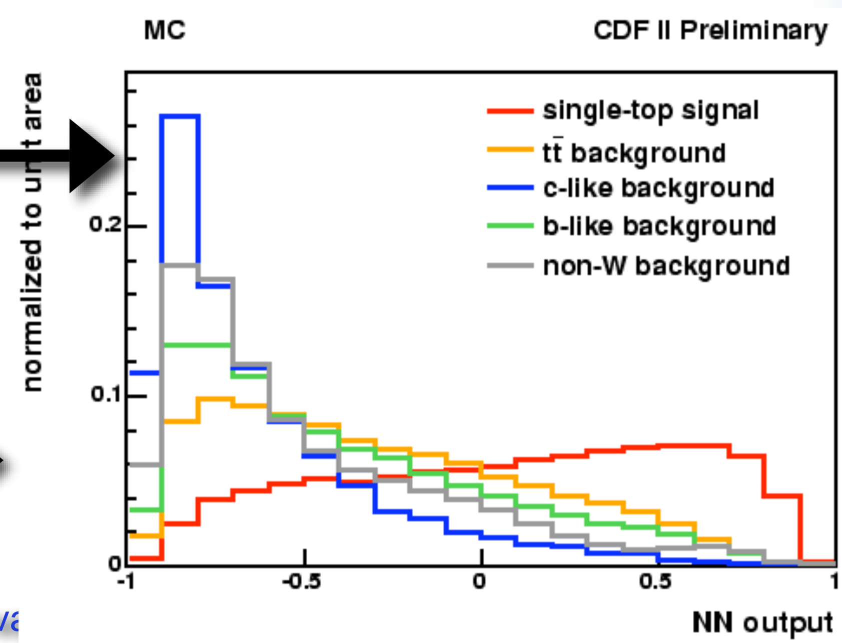
$$P(x)=\frac{1}{\sigma}\int d\sigma(y)\underline{dq_1dq_2 f(x_1)f(x_2)}W(y,x)$$

f(q) **is the probability distribution than a parton will have a momentum *q***

Neural Network Techniques

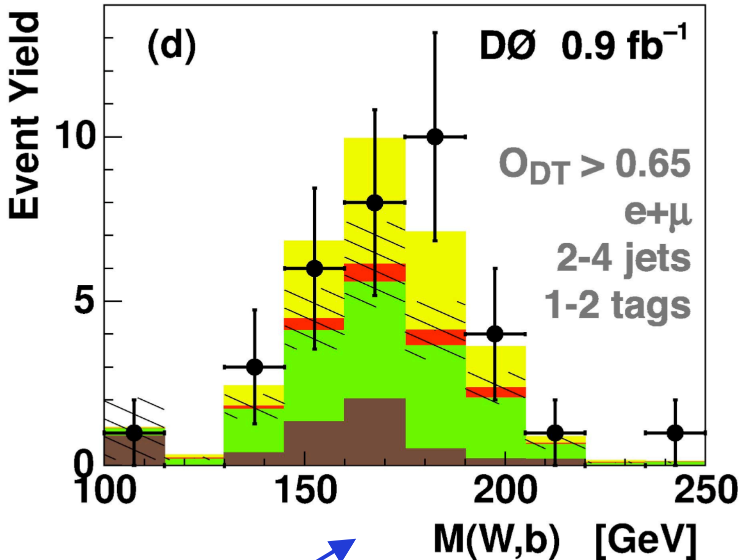






First Evidence for Single Top!

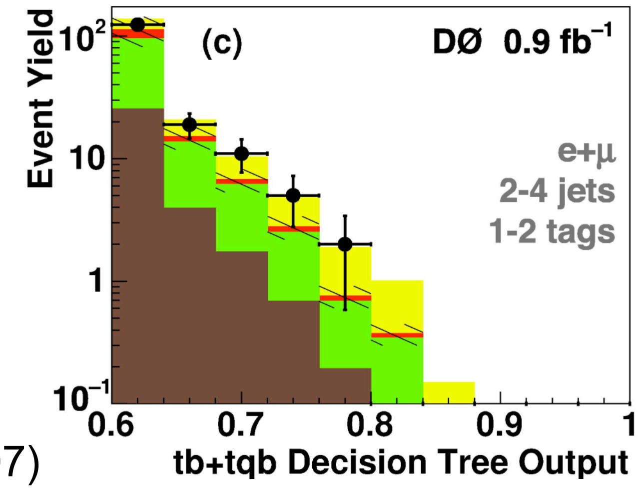
Boosted Decision Trees



0.9 fb^{-1} single top

- tb+tqb
- $t\bar{t}$
- W+jets
- Multijets

PRL 98 18102 (2007)

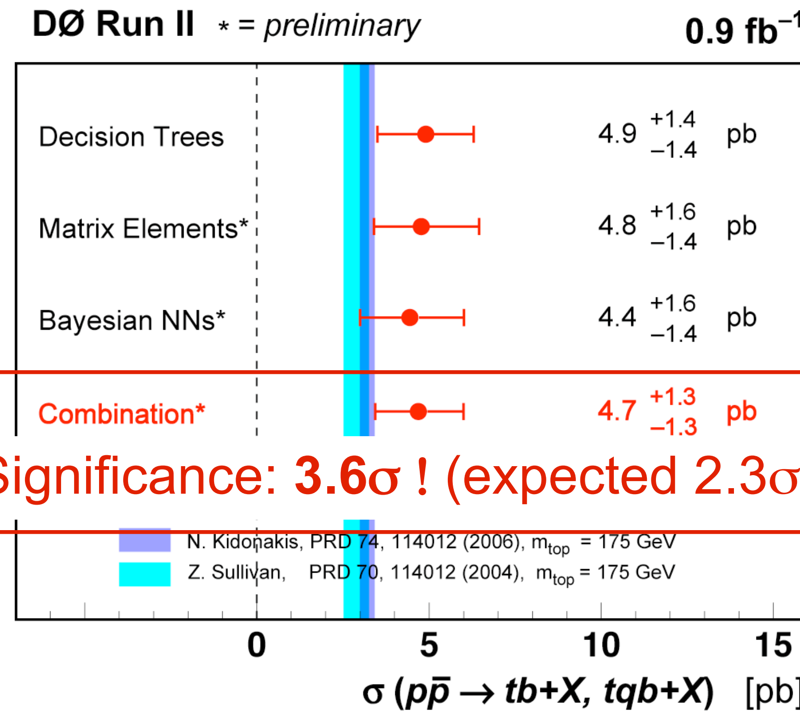


Input 49 variables: object kinematics, event kinematics, angular correlations

s-channel: $\sigma(p\bar{p} \to tb + X) = 1.0 \pm 0.9$ pb

t-channel: $\sigma(p\bar{p} \to tqb + X) = 4.2^{+1.8}_{-1.4}$ pb

s+t channels: $\sigma(p\bar{p} \to tb + X,\ tqb + X) = 4.9 \pm 1.4$ pb

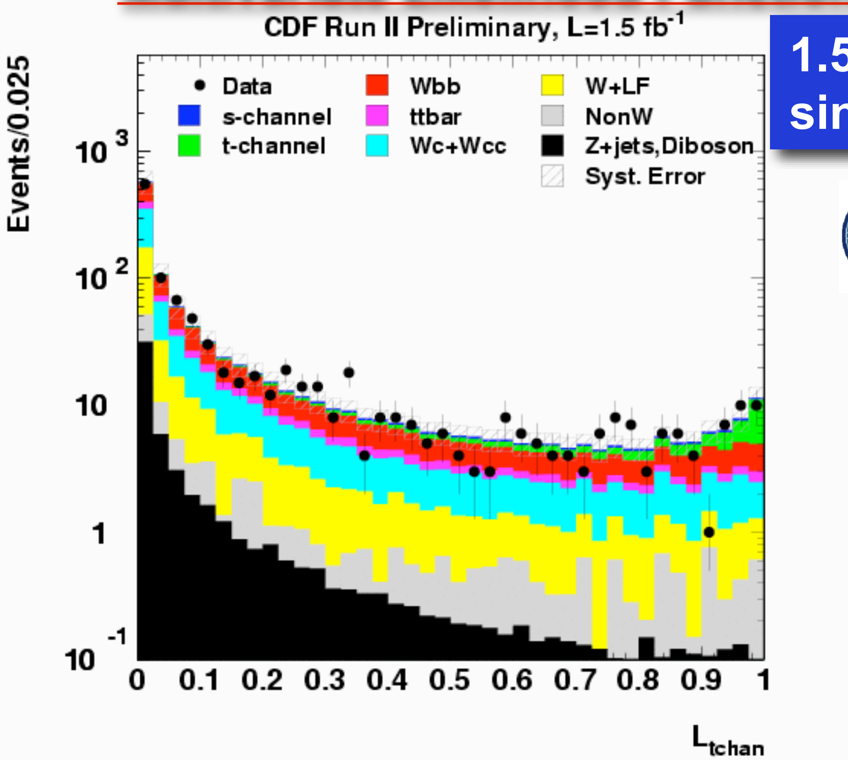


Significance: **3.6σ** ! (expected 2.3σ)

Significance of result: 3.4σ ! (expected 2.1σ)

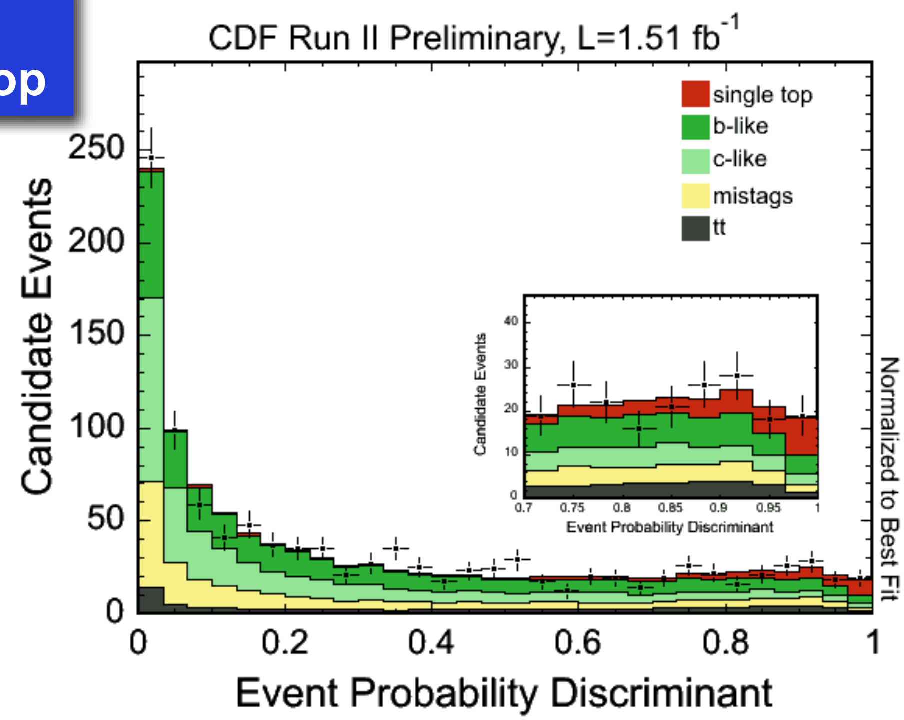
First Evidence for Single Top!

Multivariate Likelihood Function



1.5 fb^{-1} single top

Matrix Element Technique



Input 7 variables (different for s-, t- channels): kinematics, kinematic solver and ANN b-tag outputs

$$\text{s-channel}: \sigma(p\bar{p} \rightarrow tb + X) = 1.1^{+1.4}_{-1.1}\ \text{pb}$$

$$\text{t-channel}: \sigma(p\bar{p} \rightarrow tqb + X) = 1.3^{+1.2}_{-1.0}\ \text{pb}$$

$$\text{s+t channels}: \sigma(p\bar{p} \rightarrow tb + X,\ tqb + X) = 2.7^{+1.3}_{-1.1}\ \text{pb}$$

Significance of result: **2.7σ**
(expected 2.9σ)

$$\text{s-channel}: \sigma(p\bar{p} \rightarrow tb + X) = 1.1^{+1.0}_{-0.8}\ \text{pb}$$

$$\text{t-channel}: \sigma(p\bar{p} \rightarrow tqb + X) = 1.9^{+1.0}_{-0.9}\ \text{pb}$$

$$\text{s+t channels}: \sigma(p\bar{p} \rightarrow tb + X,\ tqb + X) = 3.0^{+1.2}_{-1.1}\ \text{pb}$$

Significance of result: **3.1σ** !
(expected 3.0σ)

First Direct Measurement of $|V_{tb}|$

$|V_{tb}|$ is CKM matrix element describing strength of Wtb vertex

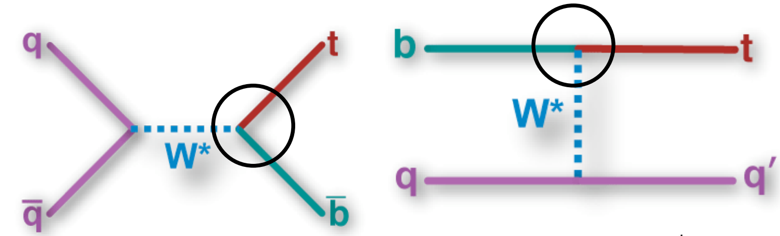
$\sigma_{single\ top} \propto |V_{tb}|^2$

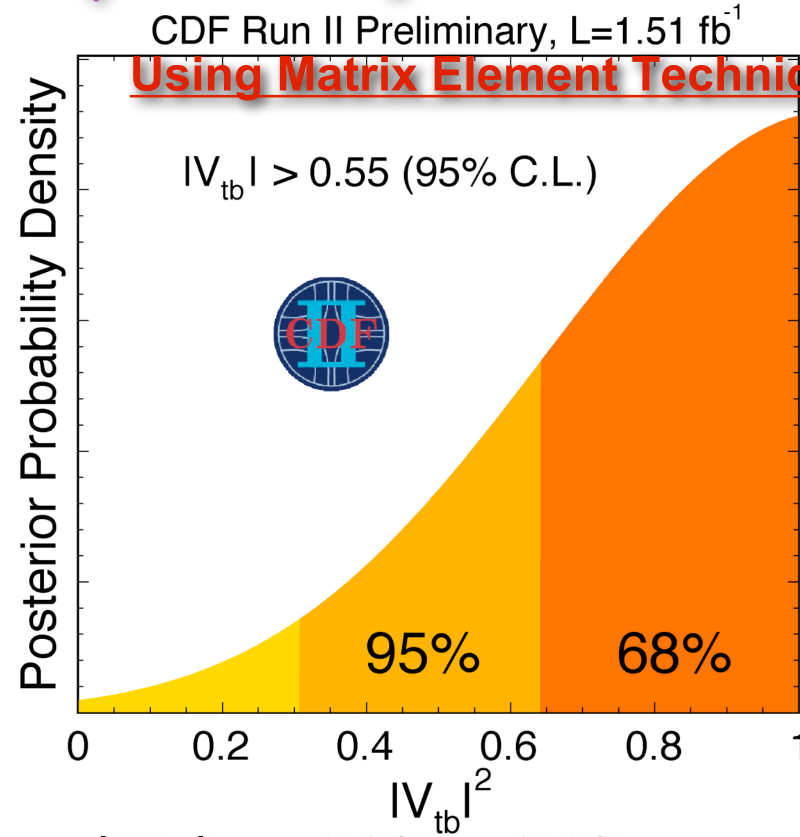
Measurement:

- Made with $\sigma_{single\ top}$
- Assumes $|V_{td}|^2 + |V_{ts}|^2 \ll |V_{tb}|^2$

Theory uncertainties:

- Arise from the cross-section dependence on the top quark mass, the factorization and renormalization scales, PDFs and α_s
- (Z. Sullivan, Phys.Rev. D70 (2004) 114012)





$$|V_{tb}| = 1.02 \pm 0.18_{experiment} \pm 0.07_{theory}$$

Using Boosted Decision Trees

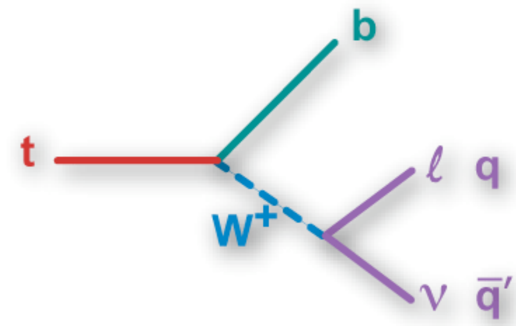
$0.68 < |V_{tb}| < 1$ @ 95%CL or

$|V_{tb}| = 1.3 \pm 0.2$

Simultaneous Measurement of σ_{ttbar} and R

In SM, $\sigma_{ttbar} \propto |V_{tq}|^2$, where $q = d, s, b$

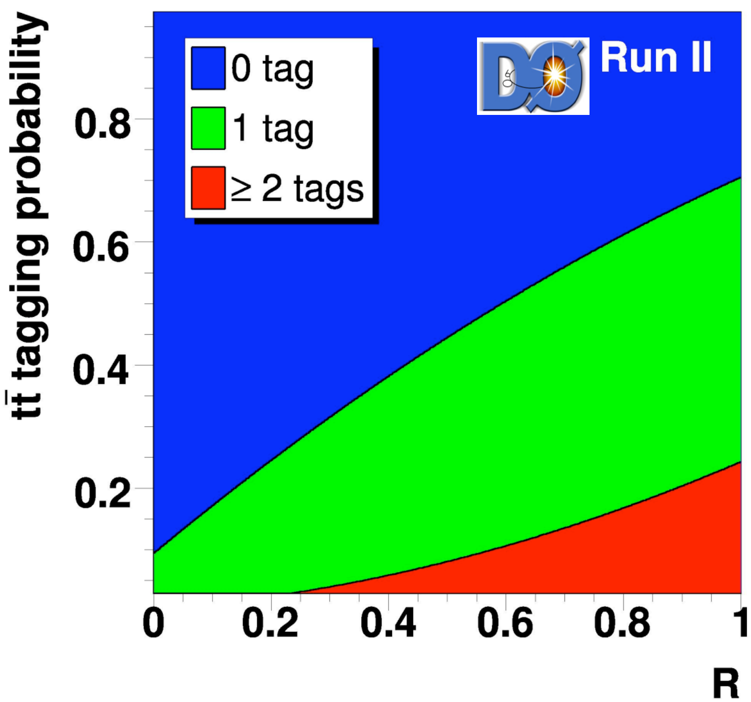
$$R = \frac{B(t \to Wb)}{B(t \to Wq)} = \frac{|V_{tb}|^2}{|V_{tb}|^2 + |V_{ts}|^2 + |V_{td}|^2} \approx 1$$



A simultaneous measurement of σ_{ttbar} and R:

- extract σ_{ttbar} without assuming $B(t \to W b) = 1$
- higher precision on both quantities

Submitted to PRL



0.9 fb^{-1} ℓ+jets

$$R = 0.97^{+0.09}_{-0.08}\,(stat + syst)$$

$$\sigma_{t\bar{t}} = 8.18^{+0.90}_{-0.84}\,(stat + syst) \pm 0.50\ (lumi)\ pb$$

for $M_{top} = 175 GeV$

A ~10% measurement of σ_{ttbar}

Use this to extract limits:

$R > 0.88 @ 68\%$ C.L. and

$|V_{tb}| > 0.89 @ 95\%$ C.L.

Is Top Pair Produced as Expected?

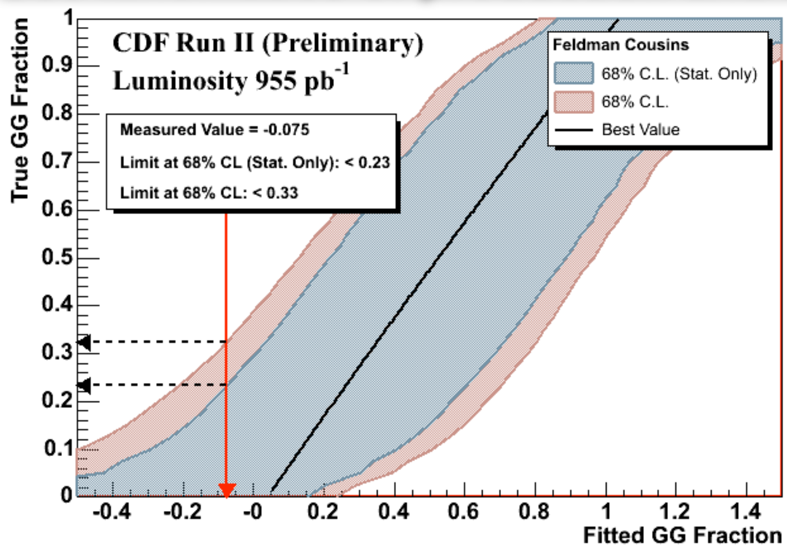
How much $gg \to t\bar{t}$ vs. $q\bar{q} \to t\bar{t}$? Large theoretical uncertainties (~10%)

Measure fraction of gg vs. qq top production

May reveal existence of unknown tt production and top quark decay mechanisms (top quark from gluino decays , and decays to stops)

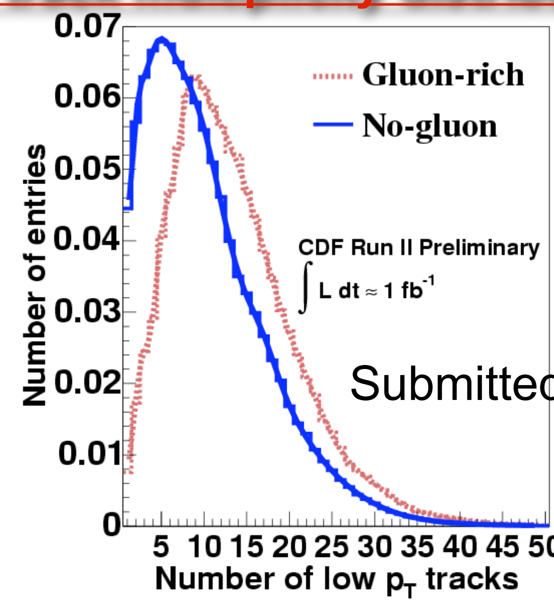
Two complementary approaches, both statistics limited

Use kinematics of production and decay



1 fb^{-1}
ℓ+jets

Use track multiplicity distribution



Submitted to PRL

$$\sigma(gg \to t\bar{t})/\sigma(p\bar{p} \to t\bar{t}) < 0.33@68\%C.L.$$

$$\sigma(gg \to t\bar{t})/\sigma(p\bar{p} \to t\bar{t}) = 0.07 \pm 0.16$$

Combination of two methods gives ~6% improvement (a posteriori).

$$\sigma(gg \to t\bar{t})/\sigma(p\bar{p} \to t\bar{t}) = 0.07^{+0.15}_{-0.07}$$

New!

Differential Cross Section $d\sigma/dM_{ttbar}$

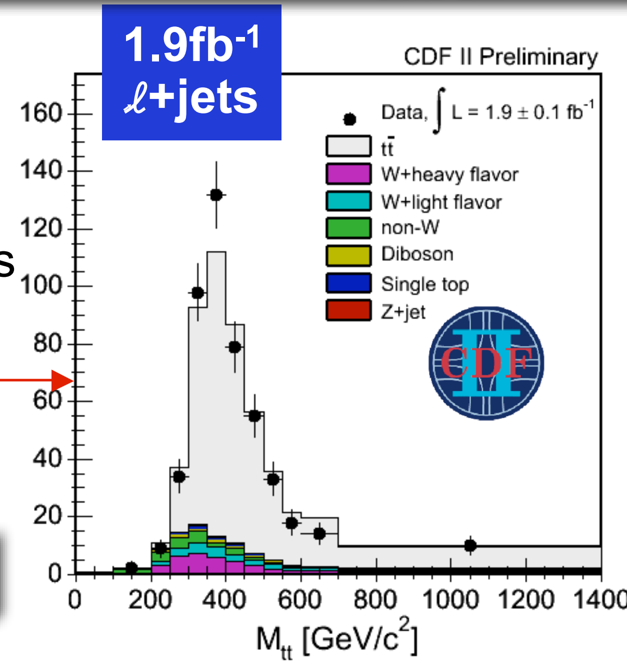
Measure $d\sigma/dM_{ttbar}$ and test consistency with SM

Possible non-SM contributions

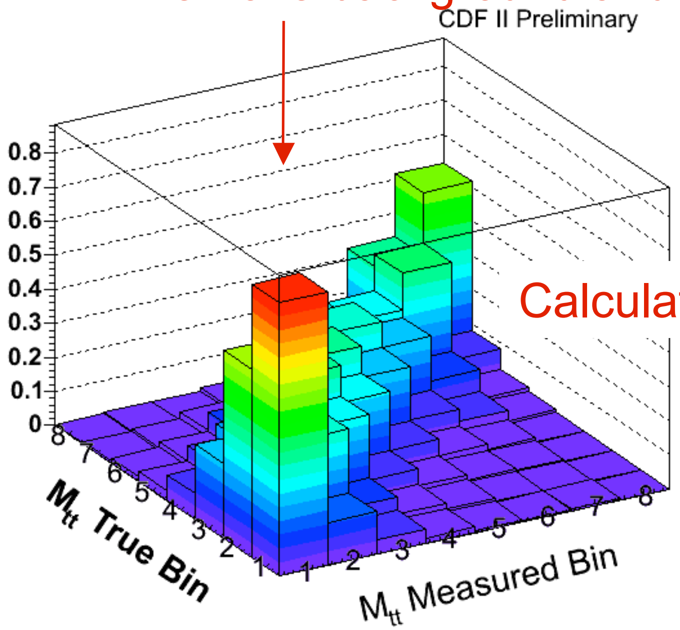
- Z', MSSM Higgs, colorons, axigluons, ...
- Sensitive to interference effects as well as resonances

$$\frac{d\sigma^i}{dM_{t\bar{t}}} = \frac{N_i - N_i^{bkg}}{\mathcal{A}_i \int \mathcal{L} \Delta^i_{M_{t\bar{t}}}}$$

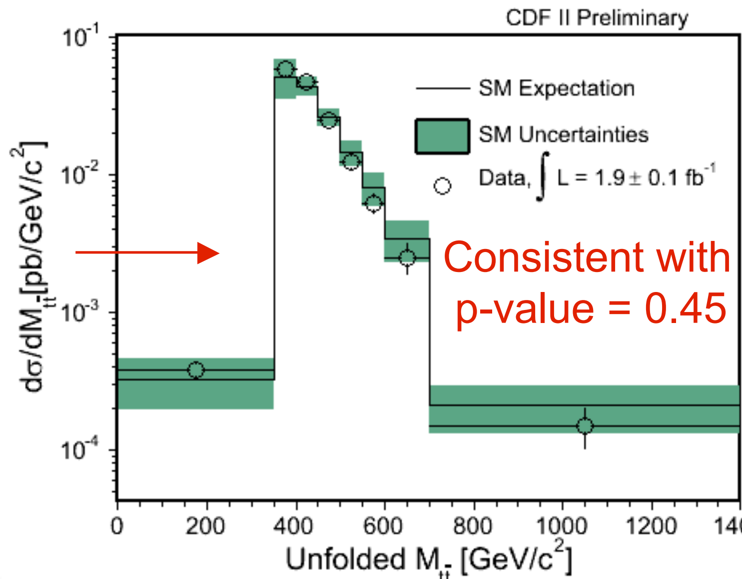
Reconstruct M_{ttbar}



Remove background and unfold



Calculate cross section



Consistent with SM
p-value = 0.45

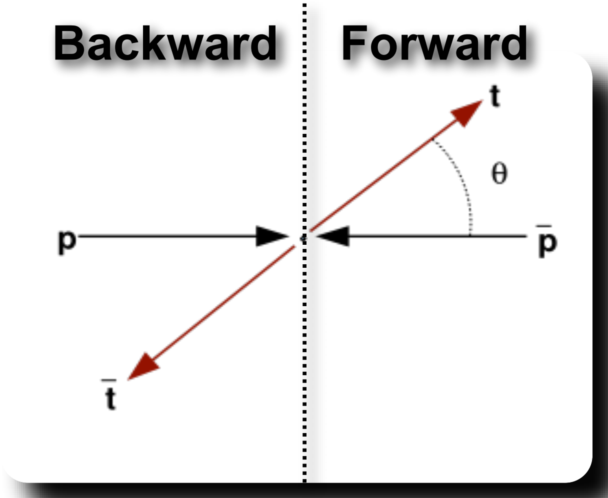
Forward Backward Production Asymmetry A_{FB}

NLO calculations predict forward-backward asymmetry of 4-6% (none at LO)

Asymmetry arises from interference between LO and higher order diagrams

Measurements in both parton rest frame and lab frame

A_{fb}(parton rest frame) = 1.3 A_{fb}(lab frame)

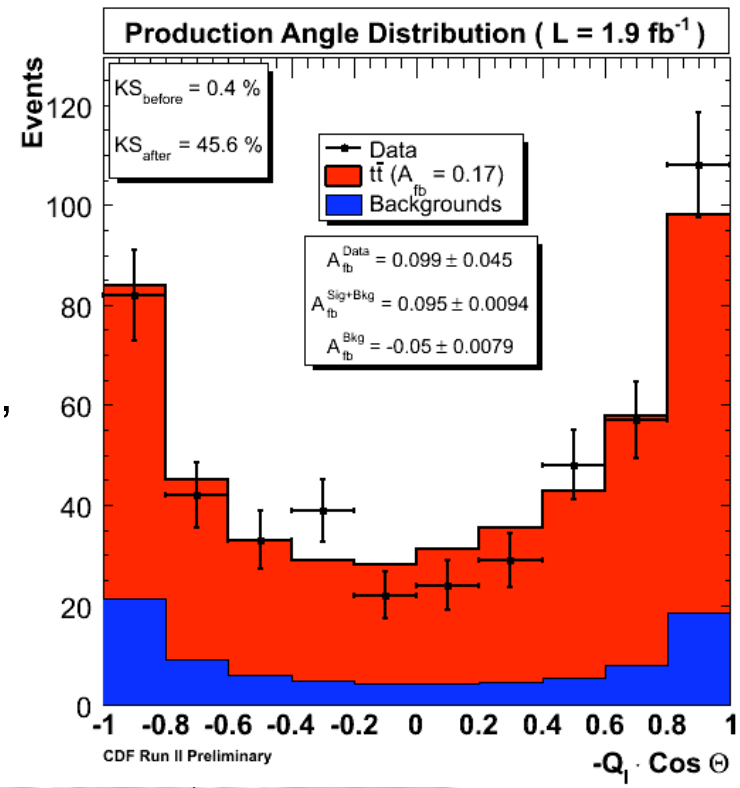


In lab frame: $$A_{fb} = \frac{N_{(-Q_\ell)\cdot Cos\Theta>0} - N_{(-Q_\ell)\cdot Cos\Theta<0}}{N_{(-Q_\ell)\cdot Cos\Theta>0} + N_{(-Q_\ell)\cdot Cos\Theta<0}}$$

In the ppbar (lab) frame for M_{top} = 175.0 GeV, after corrections

$$A_{fb} = 0.17 \pm (0.07)_{stat} \pm (0.04)_{syst}$$

$$A_{fb}^{Theory\ \mathrm{NLO}} = 0.03 - 0.05$$



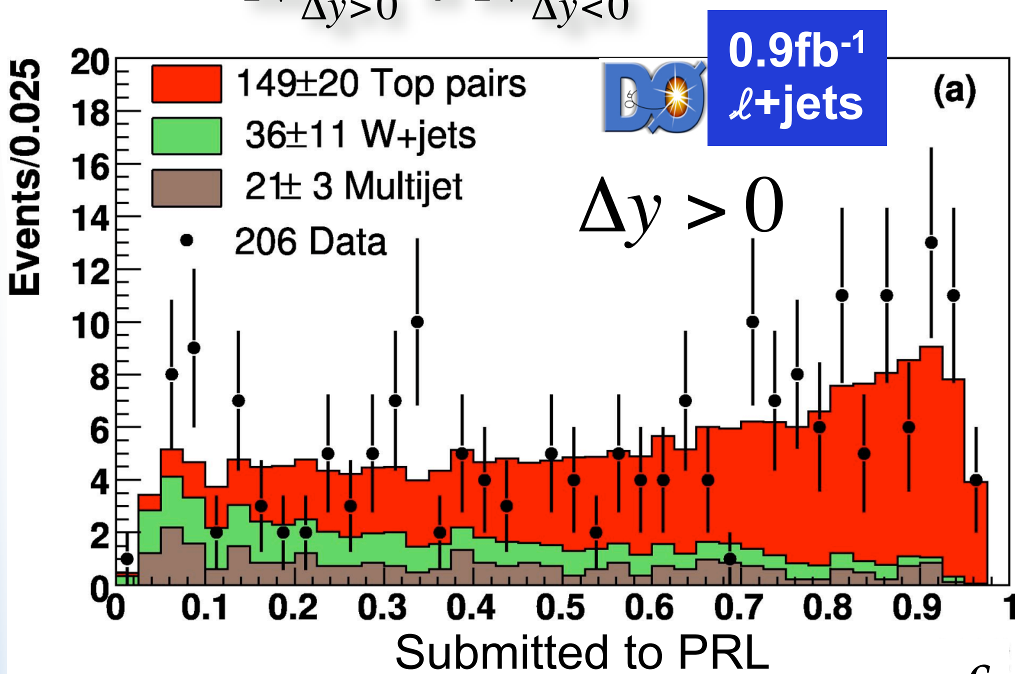
New!

1.9fb⁻¹ ℓ+jets

Forward Backward Production Asymmetry A_{FB}

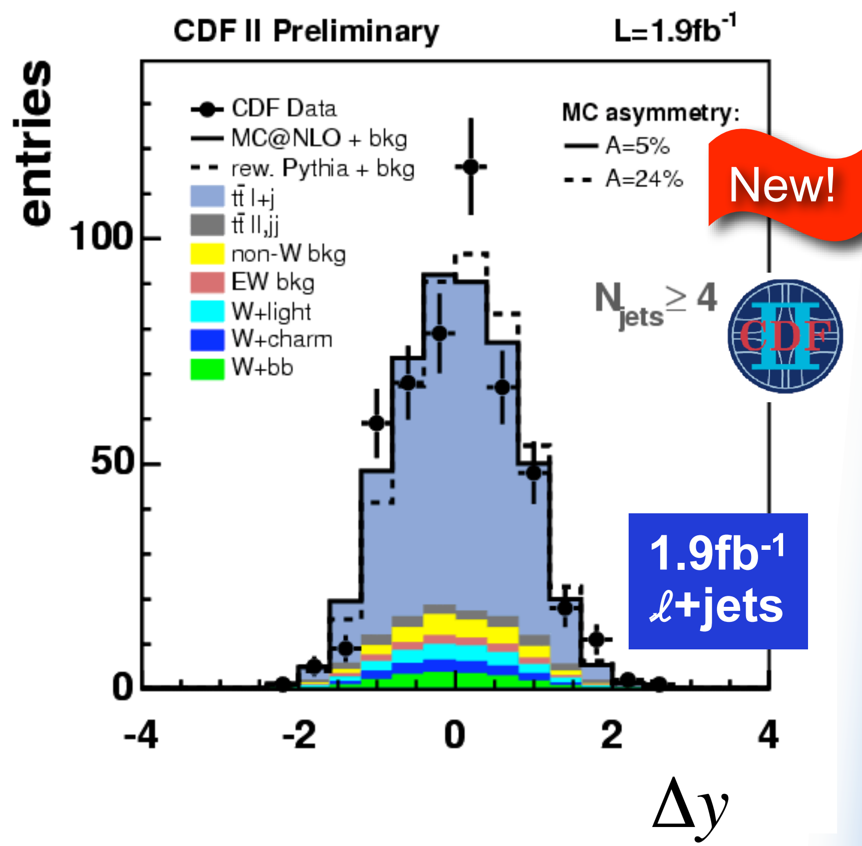
Measured in parton (t-tbar) rest frame:

$$A_{fb} = \frac{N_{\Delta y>0} - N_{\Delta y<0}}{N_{\Delta y>0} + N_{\Delta y<0}} \qquad \Delta y \equiv y_t - y_{\bar{t}} \qquad A_{fb}^{Theory\ NLO} = 0.04 - 0.06$$



$$A_{fb} = 0.12 \pm (0.08)_{stat} \pm (0.01)_{syst}$$

Uncorrected for reconstruction,
but provide geometric dilution function to be applied to any model

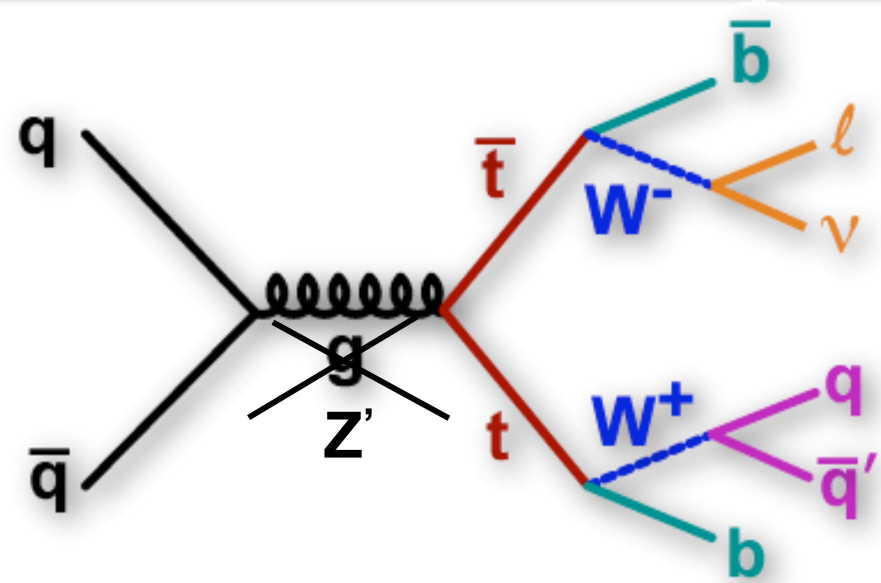


$$A_{fb} = 0.24 \pm (0.13)_{stat} \pm (0.04)_{syst}$$

Two different approaches

Fully corrected for reconstruction

Searching For New Physics In A_{FB}

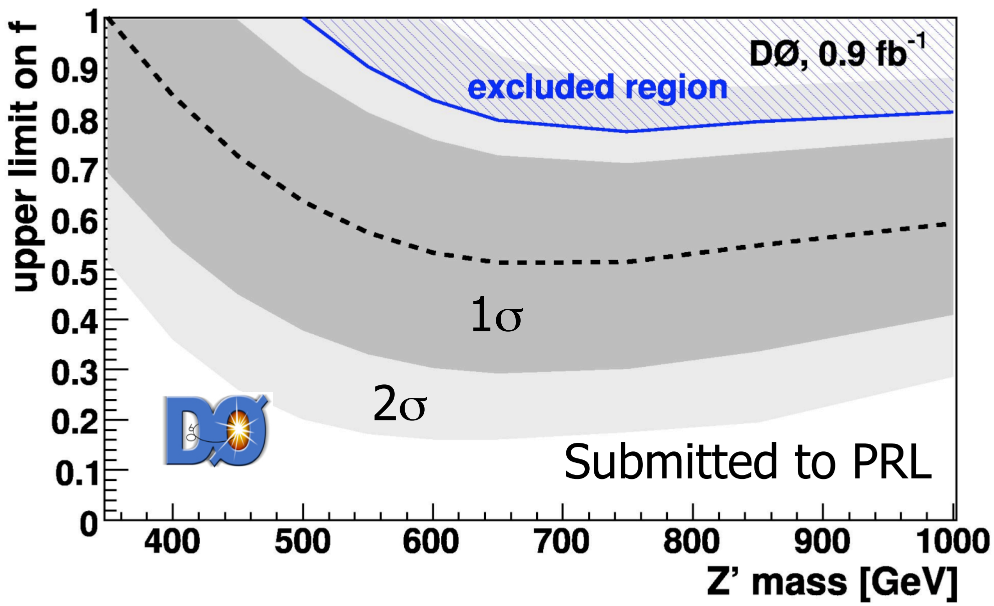


Several models suggest new particles coupled to the 3rd generation.

For example, models with a "leptophobic" Z' that decays dominantly to quarks.

Results in ttbar production via a heavy narrow (or wide) resonance.

(e.g. Harris, Hill, Parke hep-ph/9911288)



f: fraction of top pair events produced via a *wide* Z' resonance

For $M_{Z'}$ = 750 GeV:

f < 0.81 @95% C.L.(observed)

f < 0.44 @95% C.L. (expected)

Search for a ttbar Resonance

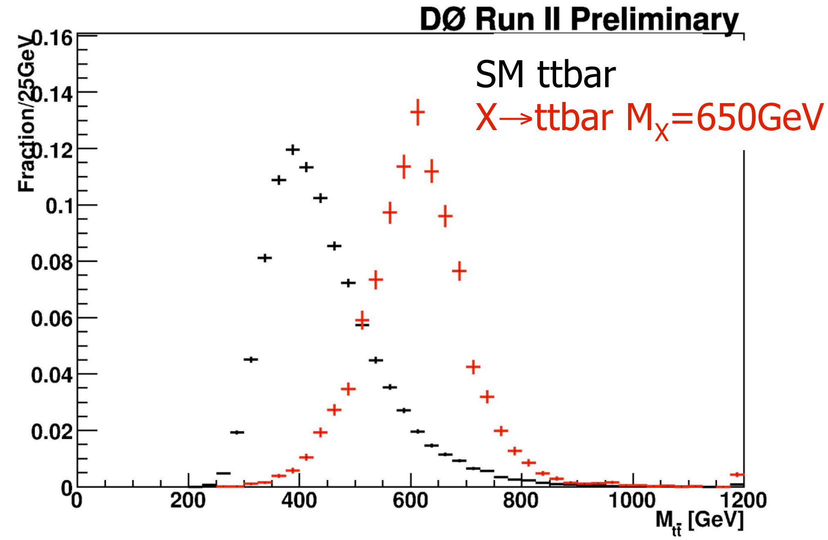
Direct search for narrow-width heavy resonance

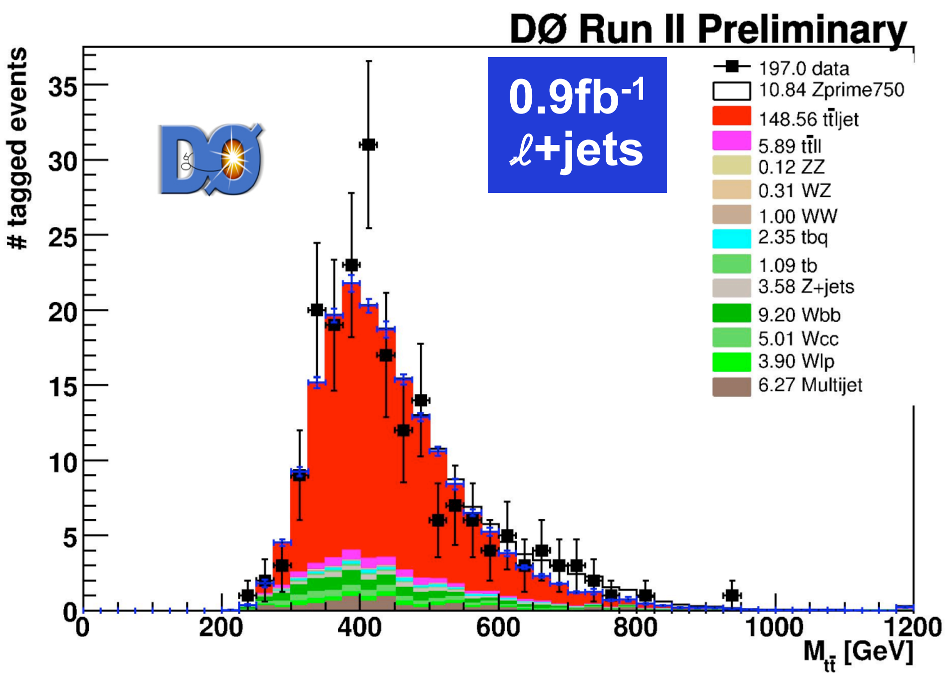
Analyze reconstructed M_{ttbar} distribution

Within a topcolor-assisted technicolor model, exclude leptophobic Z':

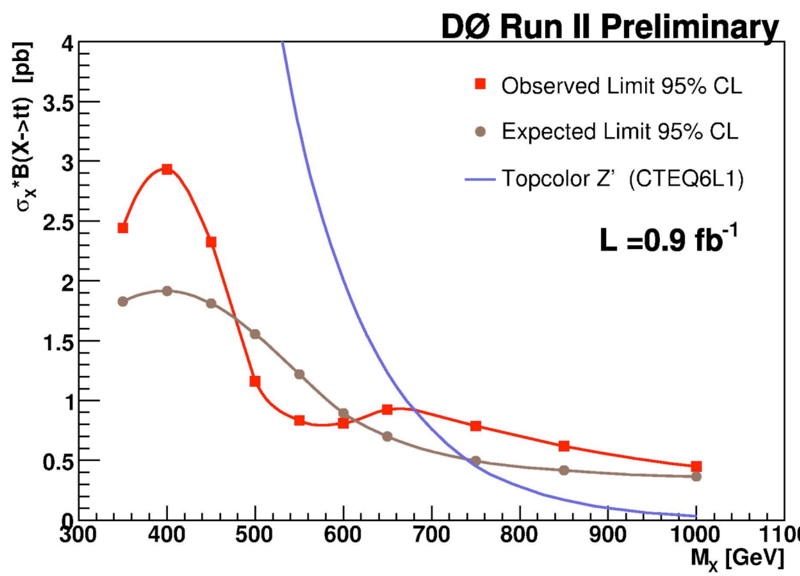
$M_{Z'}$<680 GeV (Γ=0.012 $M_{Z'}$)

excluded at 95%C.L.

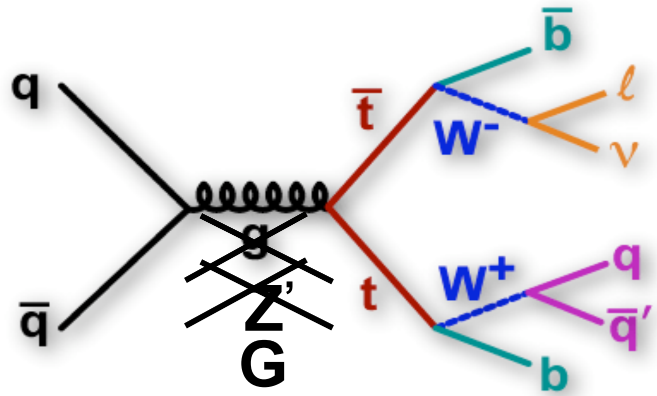




$$\sigma_{X^0} \cdot \mathscr{B}(X^0 \to t\bar{t}) \text{ versus } M_{X^0}$$



Search for a Massive Gluon



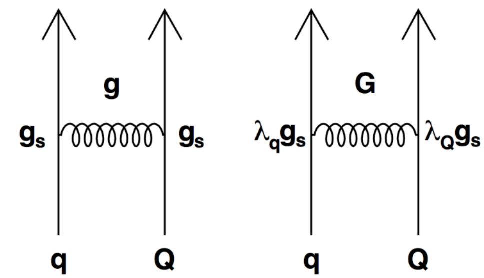
New!

1.9fb^{-1}
ℓ+jets

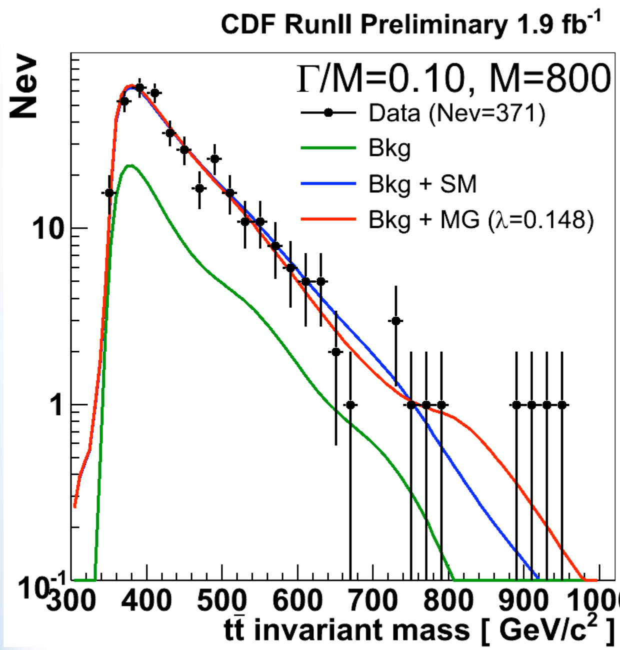
Search for heavy gluon-like particle, G→ttbar

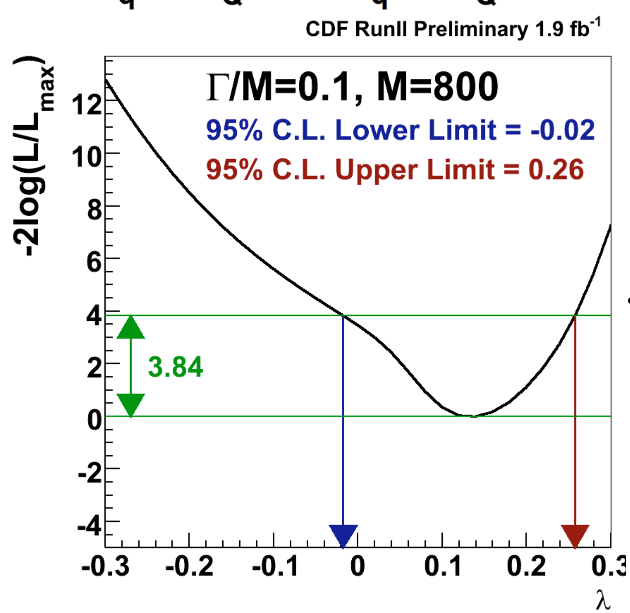
Analyze reconstructed M_{ttbar} distribution with a Matrix Element technique (DLM)

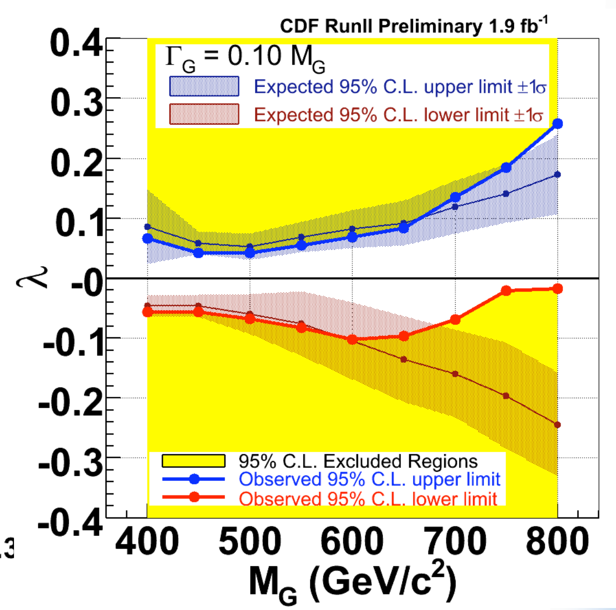
Set upper and lower limits on coupling strength, $\lambda=\lambda_q\lambda_Q$, for Γ_G=5-50%M_G and M_G=400-800GeV



Γ_G=0.1M_G, M_G=800 GeV
95%C.L. Lower Limit = -0.02
95%C.L Upper Limit = 0.26







Search for a W' Resonance

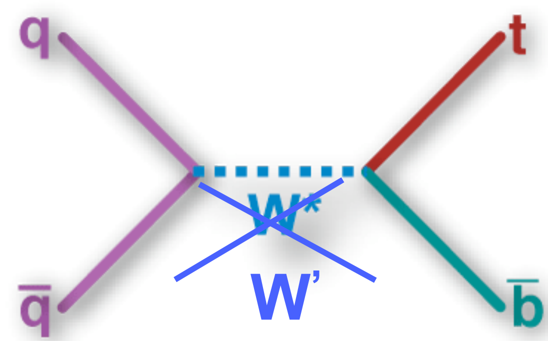
Search for resonances in tb channel using M_{WJJ}

Use massive W boson, or W´, to model such a resonance

W´ with SM couplings has a large branching fraction to tb

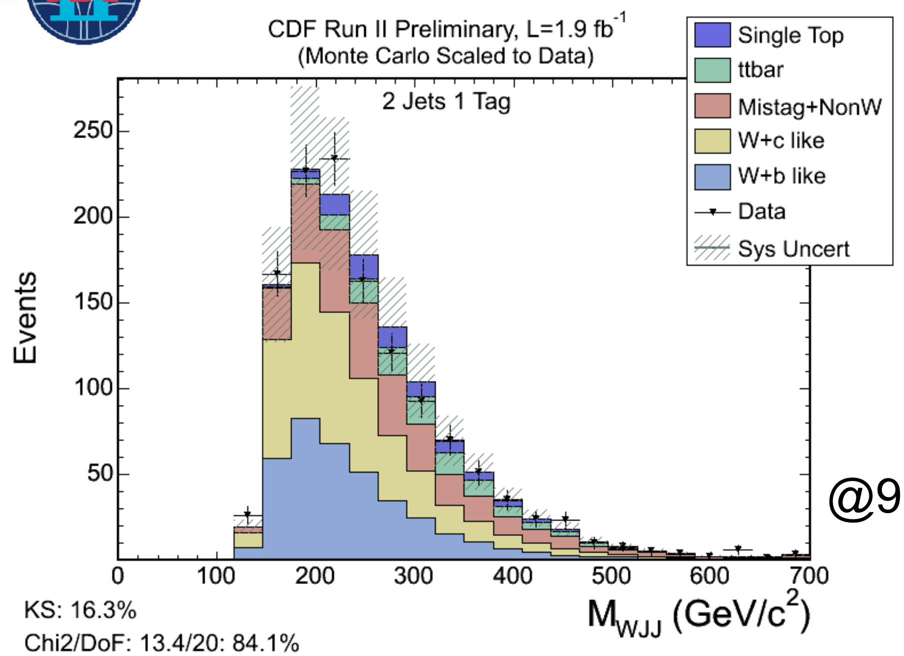
Many new theories include new gauge bosons:

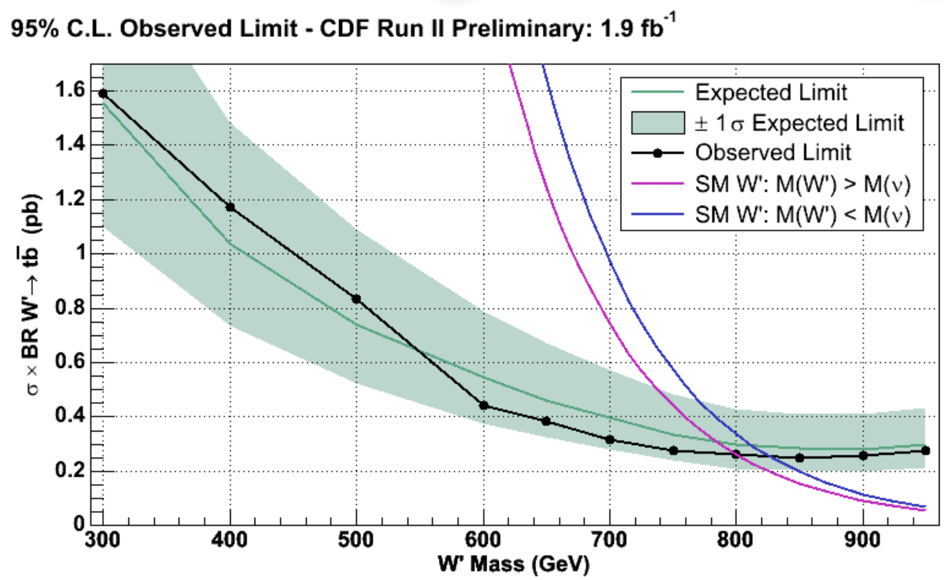
- Extensions to the Standard Model (GUT)
- Extra dimensions (Kaluza-Klein)



New!

$1.9 fb^{-1}$ single-top





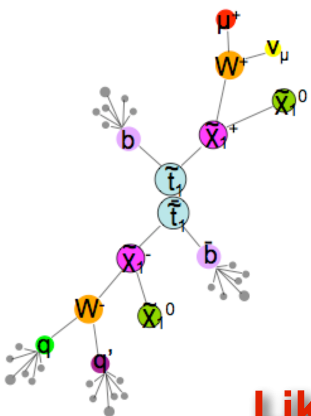
@95%C.L.

$$M_{W'} > 800\ GeV/c^2 \quad (M_{W'} > M_{\nu_R})$$

$$M_{W'} > 825\ GeV/c^2 \quad (M_{W'} < M_{\nu_R})$$

(Branching ratio depends whether $W'_R \to l\nu_R$ is kinematically allowed)

Search for Scalar Top



What about SUSY? Search for superpartner of top quark

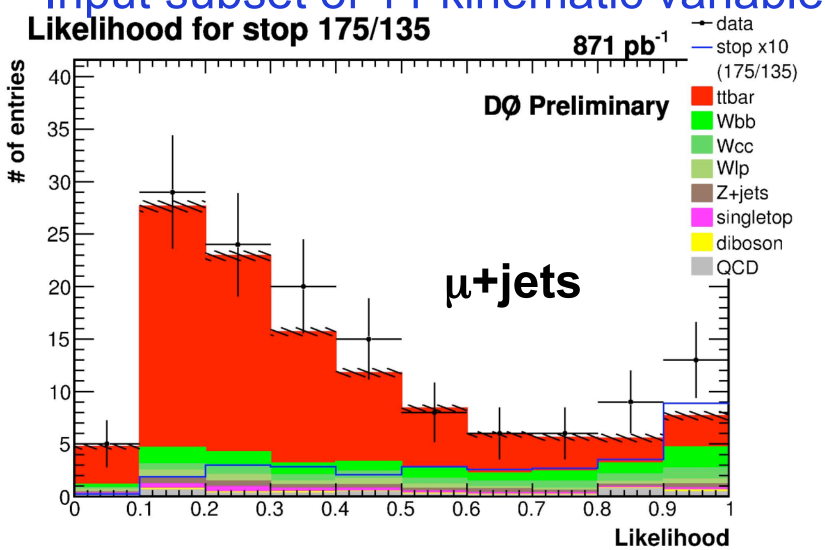
Consider stop quark masses equal to or lighter than the top quark mass

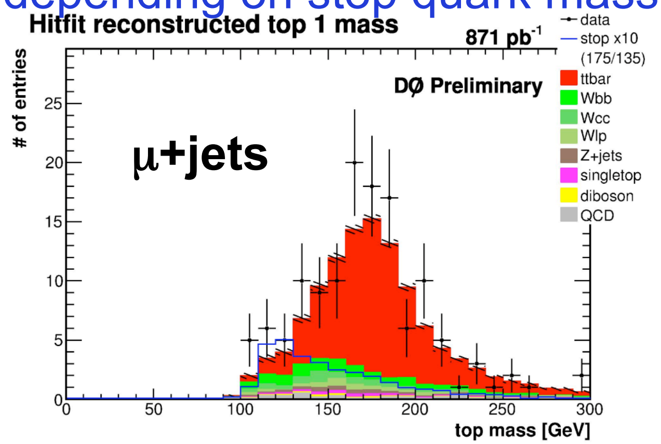
$\tilde{t} \rightarrow b\tilde{\chi}_1^+ \; (\tilde{\chi}_1^+ \rightarrow W^+\tilde{\chi}_1^0)$ can be important

0.9fb^{-1}
ℓ+jets

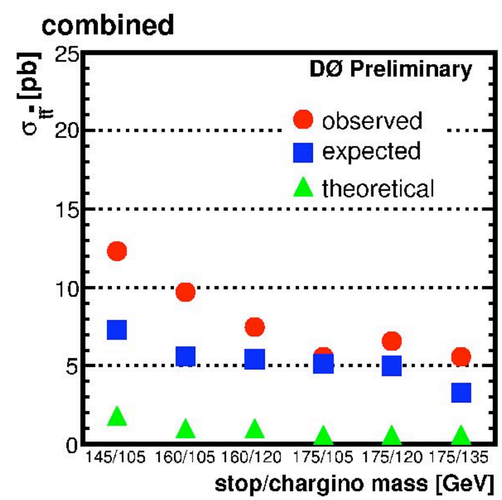
Likelihood Discriminant

Input subset of 11 kinematic variables, depending on stop quark mass point





e+μ



First time search done in this channel in Run II.

Obtain upper cross section limits @ 95% C.L. for stop (chargino) masses of 145-175 (105-135) GeV.

Observed limits are a factor of ~7-12 above the theoretical predictions

Charged Higgs Limits

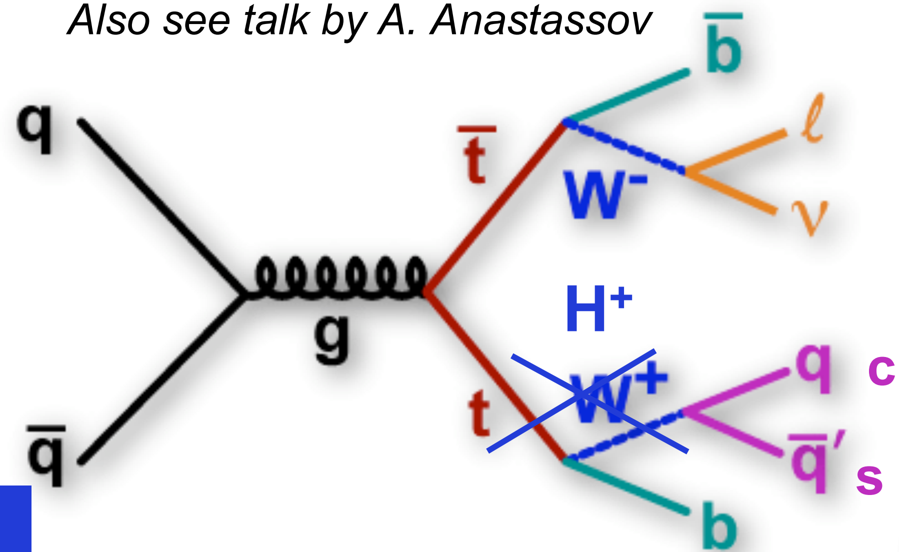
Also see talk by A. Anastassov

In SM, cross section ratio expectation:

$$R_\sigma = \frac{\sigma(p\bar{p} \to t\bar{t})_{\ell+jets}}{\sigma(p\bar{p} \to t\bar{t})_{\ell\ell}} = 1$$

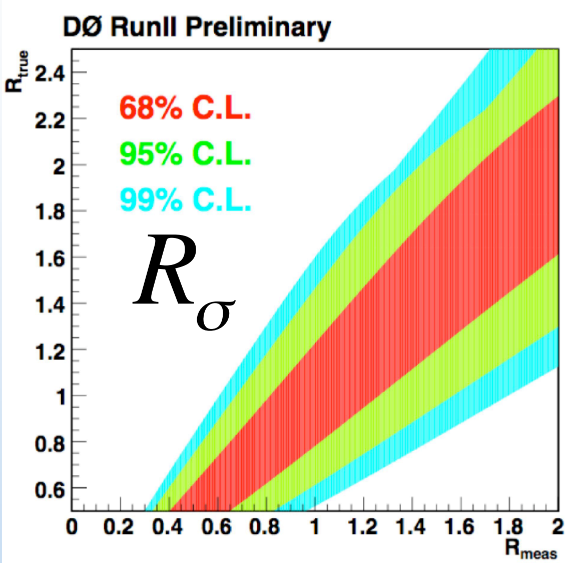
Measurement in agreement with SM:

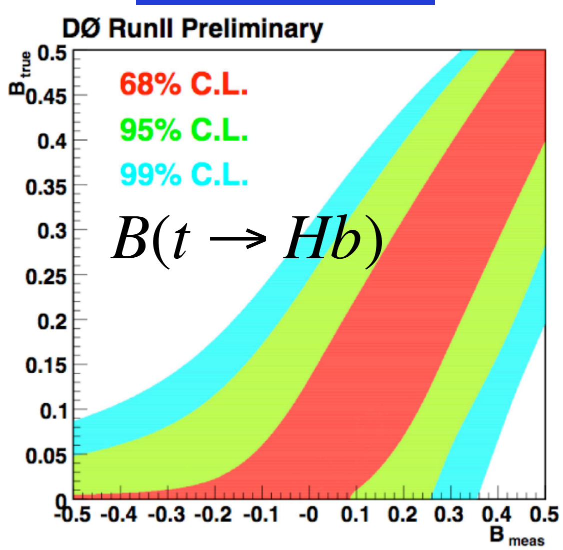
$$\mathbf{R}_\sigma = \frac{\sigma(\mathbf{p\bar{p}} \to \mathbf{t\bar{t}})_{\ell+\mathbf{jets}}}{\sigma(\mathbf{p\bar{p}} \to \mathbf{t\bar{t}})_{\ell\ell}} = \mathbf{1.21^{+0.27}_{-0.26}(stat + syst)}$$



Confidence Intervals

1 fb^{-1}
ℓ+jets & ℓ ℓ





Interpret R_σ into upper limit on:

$$\mathbf{B(t \to Hb) < 0.35@95\%C.L.}$$

With SM expectation of:

$$B(t \to Hb) < 0.25@95\%C.L.$$

Assumptions:

M_{H^+} = 80GeV (not ruled out by LEP)

and decays exclusively to $H^{+(-)} \to c\bar{s}(\bar{c}s)$.

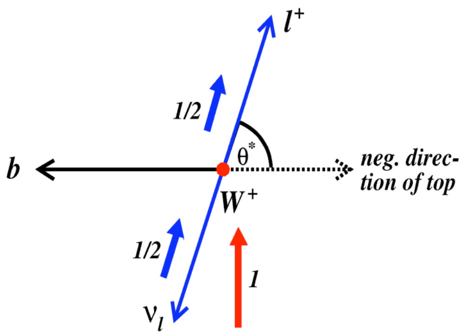
W Helicity

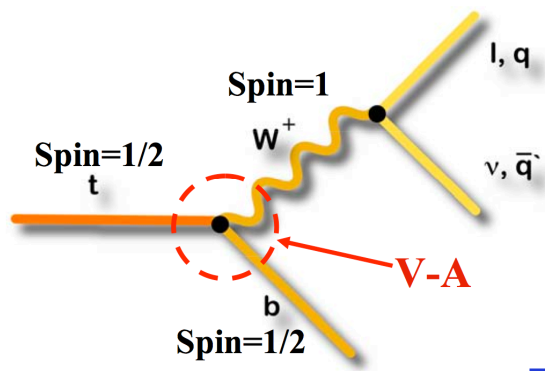
The V-A character of the decay makes the helicity of the W only

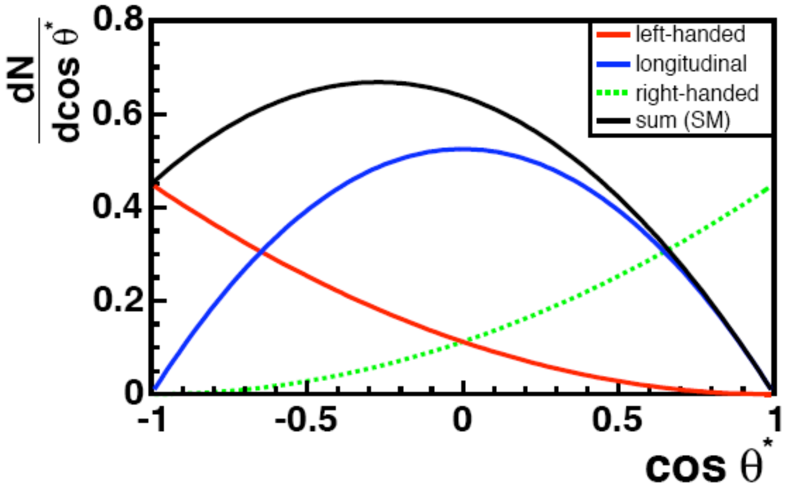
$F_0 = 0.70$, $F_- = 0.30$, $F_+ = 0$

(longitudinal, left-handed, right-handed)

1 fb^{-1}

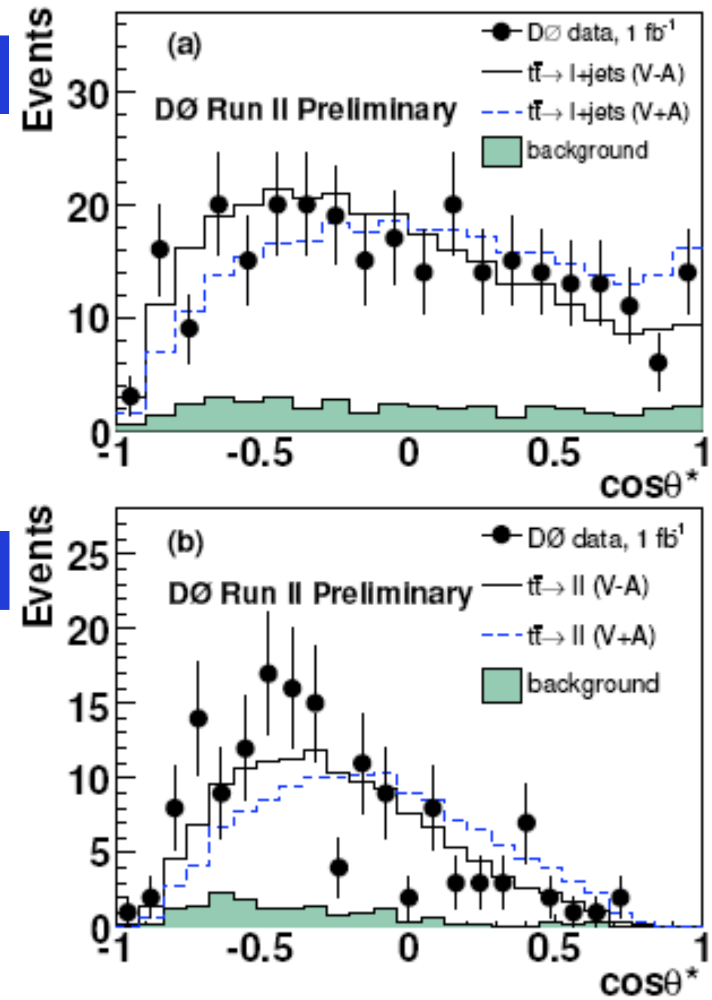






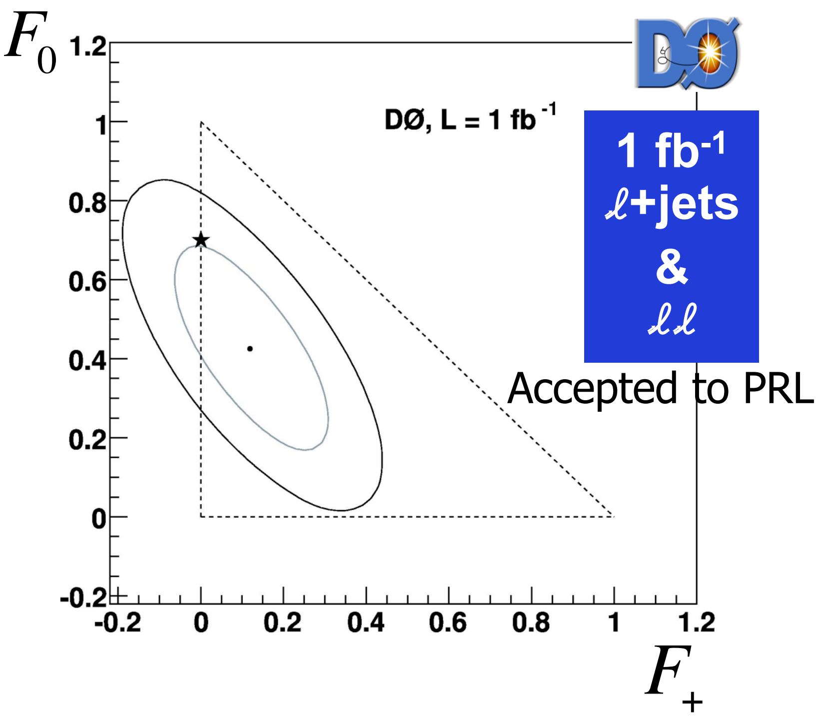
ℓ+jets

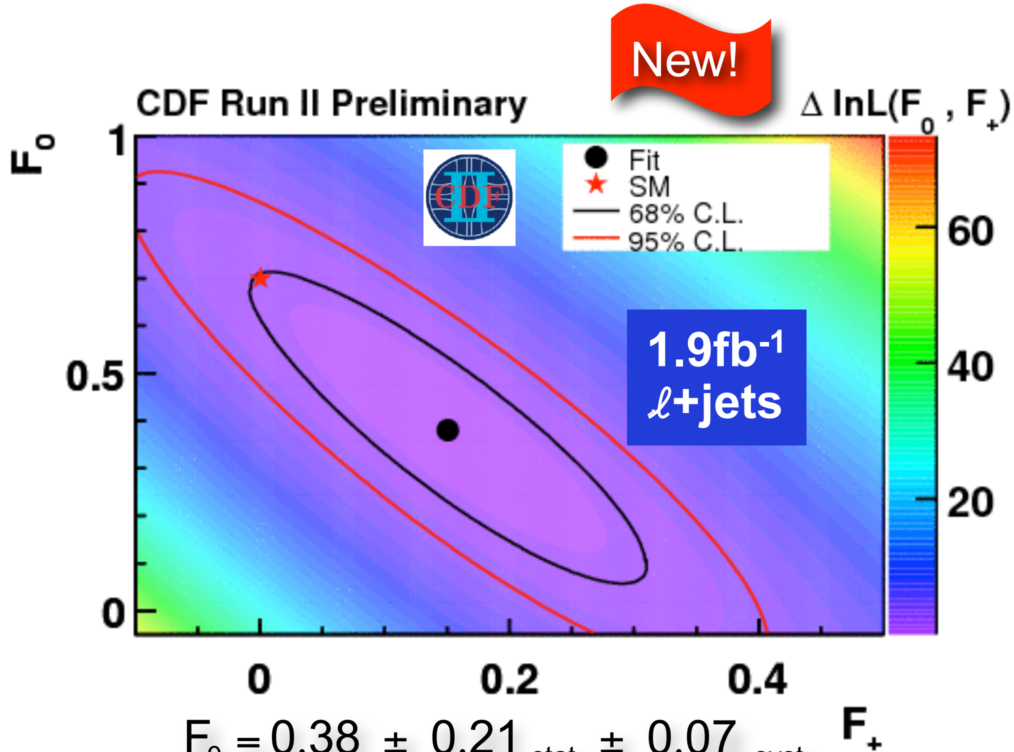
$\ell\ell$



cosθ^* = angle between lepton and top in W rest frame

W Helicity Measurements using cosθ*





$F_0 = 0.425 \pm 0.166_{stat} \pm 0.102_{syst}$

$F_+ = 0.119 \pm 0.090_{stat} \pm 0.053_{syst}$

If F_+ fixed to 0:

$F_0 = 0.619 \pm 0.090_{stat} \pm 0.052_{syst}$

If F_0 fixed to 0.7:

$F_+ = -0.002 \pm 0.047_{stat} \pm 0.047_{syst}$

$F_0 = 0.38 \pm 0.21_{stat} \pm 0.07_{syst}$

$F_+ = 0.15 \pm 0.10_{stat} \pm 0.05_{syst}$

If F_+ fixed to 0:

$F_0 = 0.66 \pm 0.10_{stat} \pm 0.06_{syst}$

If F_0 fixed to 0.7:

$F_+ = 0.01 \pm 0.05_{stat} \pm 0.03_{syst}$

W Helicity Matrix Element Technique

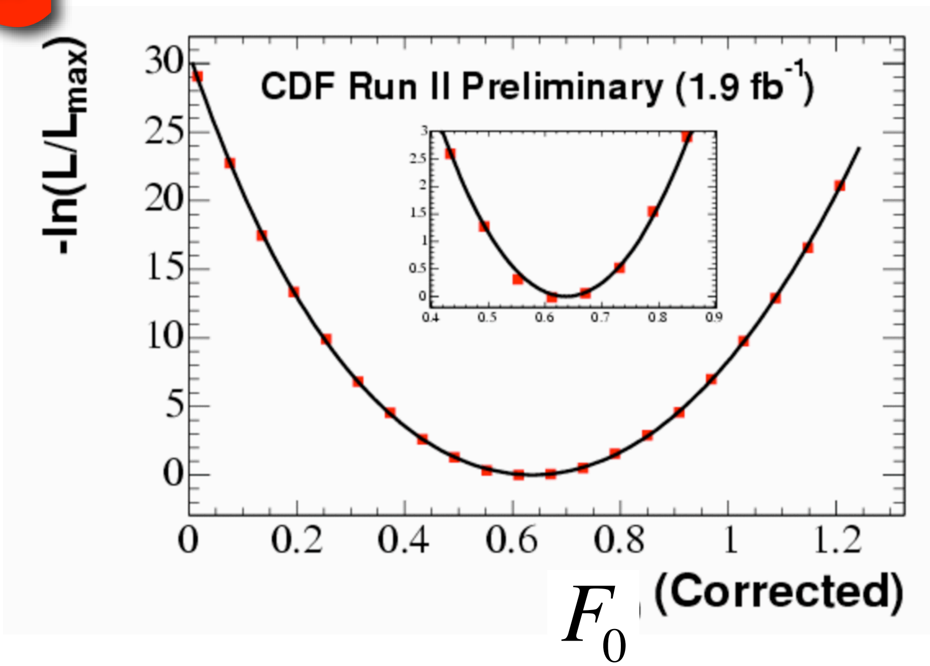
Matrix Element Technique Likelihood based on differential cross sections for ttbar and W+jets

$$\mathcal{L} = (F_0, C_s) = \prod_{i=1}^{N} C_s P_{t\bar{t}}(\vec{x}_i; F_0) + (1 - C_s) P_{W+jets}(\vec{x}_i)$$

$$d\sigma \propto |M|^2, |M|^2 \propto w_{lep}(\cos\theta^*) \times w_{had}(\cos\theta^*)$$

$$w(\cos\theta^*) = F_+ \frac{3}{8}(1-\cos\theta^*)^2 + F_0 \frac{3}{4}(1-\cos^2\theta^*) + (1 - F_0 - F_+)\frac{3}{8}(1+\cos\theta^*)^2$$

New!



1.9fb^{-1} ℓ+jets

$F_0 = 0.637 \pm 0.084_{stat} \pm 0.069_{syst}$

for M_{top} = 175 GeV/c^2

and $F_+ = 0$

~20% improvement in sensitivity!

Conclusions

The top quark is the least known quark, and the most interesting for new physics.

Lots of exciting top physics happening at the Tevatron!
(Many topics I didn't have time to cover:
t', FCNC, Top Charge, Top Width, …)

We are unraveling the true nature of the top quark.

Beginning to have sensitivity to the unexpected in particle properties and new phenomena in the data.

Frustratingly consistent with standard model, so far.

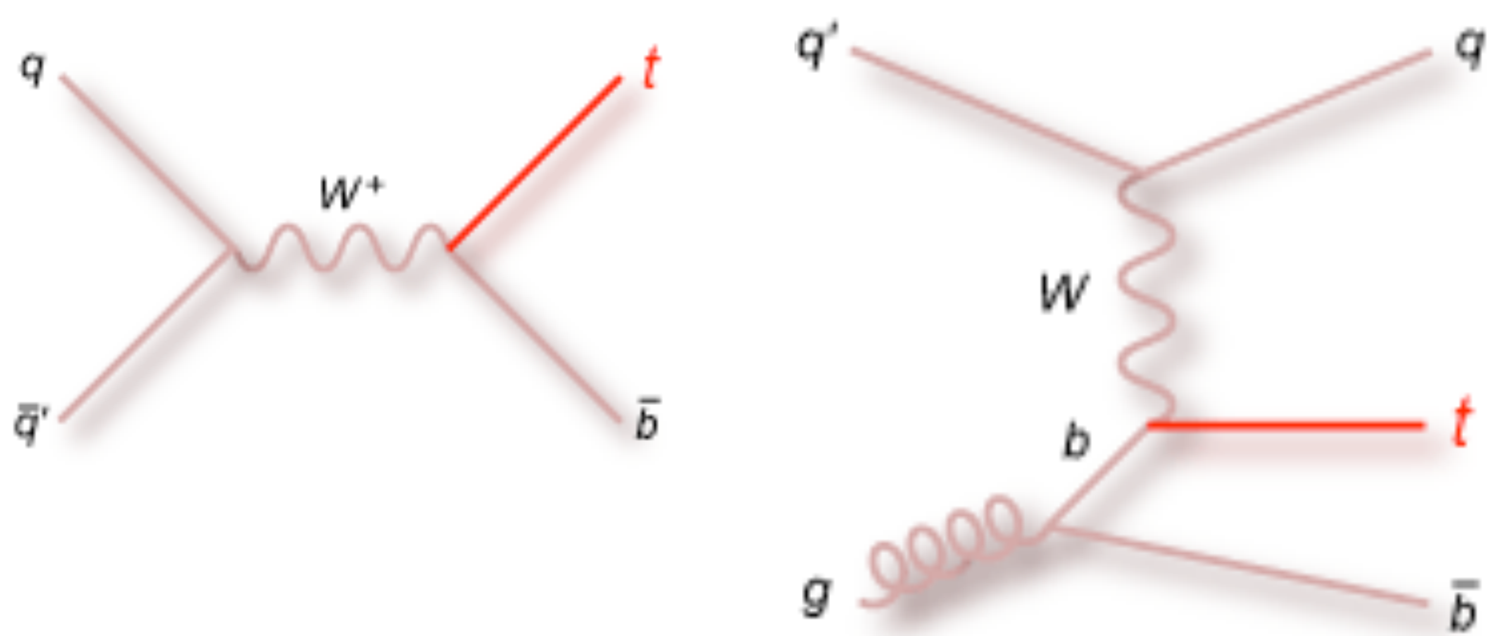
For more info go to:

http://www-cdf.fnal.gov/physics/new/top/top.html

http://www-d0.fnal.gov/Run2Physics/top/top_public_web_pages/top_public.html

BACKUP

Single Top

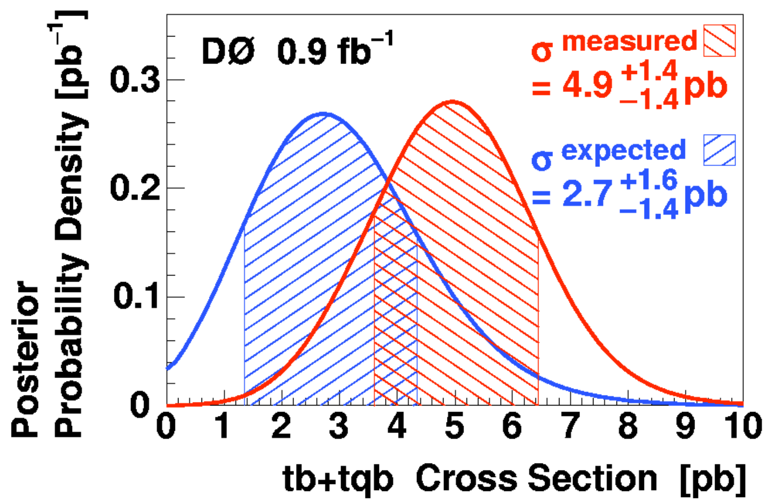


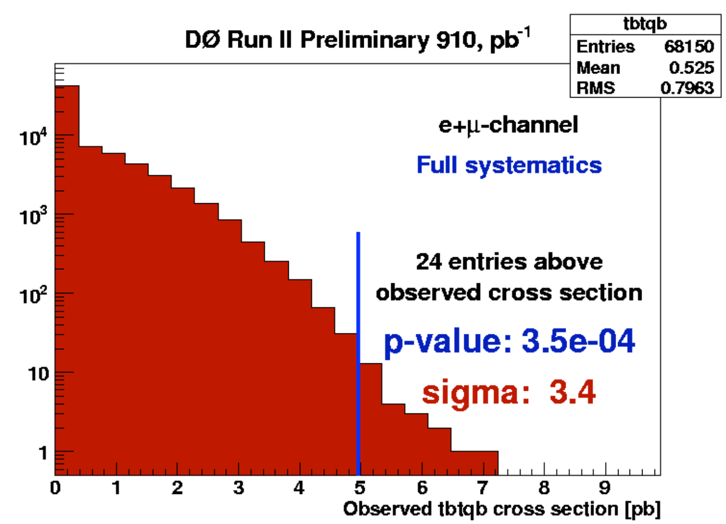
Single Top DØ

Summary table

	Exp p-value (std.dev.)	Obs p-value (std.dev.)	p-value SM (std.dev.)	Frequency
DT	0.019 (2.1)	0.00035 (3.4)	0.11 (1.2)	60%
ME	0.037 (1.8)	0.0021 (2.9)	0.21 (0.8)	62%
BNN	0.097 (1.3)	0.0089 (2.4)	0.175 (0.9)	59%

- Expected p-value: Fraction of zero-signal pseudo-datasets above SM cross section (2.9 pb)
- Observed p-value: Fraction of zero-signal pseudo-datasets above measured cross section
- p-value SM: Fraction of SM-signal pseudo-datasets (including 16% uncertainty on the signal cross section) above measured cross section
- Frequency: Fraction of measured-cross-section signal pseudo-datasets (including 16% uncertainty on the signal cross section) that fall within the 1 standard deviation error bands of the observed value





Single Top DØ

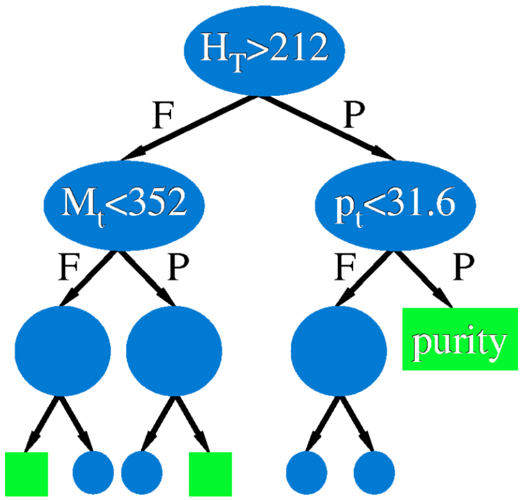
Percentage of single top *tb+tqb* selected events and S:B ratio (white squares = no plans to analyze)

Electron + Muon	1 jet	2 jets	3 jets	4 jets	≥ 5 jets
0 tags	10% 1 : 3,200	25% 1 : 390	12% 1 : 300	3% 1 : 270	1% 1 : 230
1 tag	6% 1 : 100	21% 1 : 20	11% 1 : 25	3% 1 : 40	1% 1 : 53
2 tags		3% 1 : 11	2% 1 : 15	1% 1 : 38	0% 1 : 43

Single Top DØ

Source	Event Yields in 0.9 fb^{-1} Data Electron+muon, 1tag+2tags combined 2 jets	3 jets	4 jets
tb	16 ± 3	8 ± 2	2 ± 1
tqb	20 ± 4	12 ± 3	4 ± 1
$t\bar{t} \rightarrow ll$	39 ± 9	32 ± 7	11 ± 3
$t\bar{t} \rightarrow l$+jets	20 ± 5	103 ± 25	143 ± 33
$W+b\bar{b}$	261 ± 55	120 ± 24	35 ± 7
$W+c\bar{c}$	151 ± 31	85 ± 17	23 ± 5
$W+jj$	119 ± 25	43 ± 9	12 ± 2
Multijets	95 ± 19	77 ± 15	29 ± 6
Total background	686 ± 41	460 ± 39	253 ± 38
Data	697	455	246

Single Top DØ



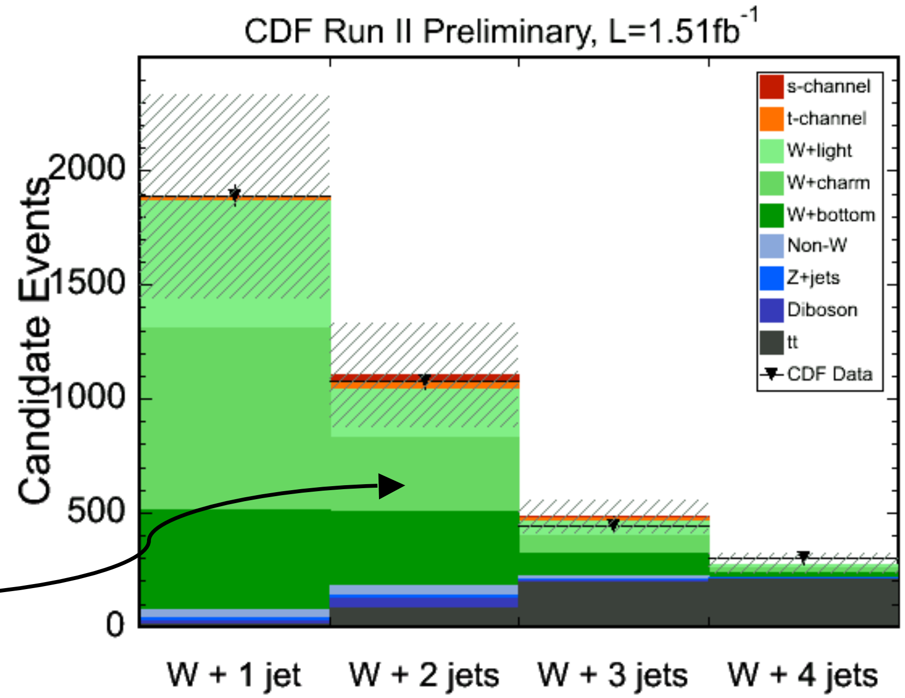
Decision Tree Input Variables

Object Kinematics	**Event Kinematics**
p_T(jet1)	Aplanarity(alljets,W)
p_T(jet2)	M(W,best1) ("best" top mass)
p_T(jet3)	M(W,tag1) ("b-tagged" top mass)
p_T(jet4)	H_T(alljets)
p_T(best1)	H_T(alljets$-$best1)
p_T(notbest1)	H_T(alljets$-$tag1)
p_T(notbest2)	H_T(alljets,W)
p_T(tag1)	H_T(jet1,jet2)
p_T(untag1)	H_T(jet1,jet2,W)
p_T(untag2)	M(alljets)
	M(alljets$-$best1)
Angular Correlations	M(alljets$-$tag1)
ΔR(jet1,jet2)	M(jet1,jet2)
cos(best1,lepton)$_{\text{besttop}}$	M(jet1,jet2,W)
cos(best1,notbest1)$_{\text{besttop}}$	M_T(jet1,jet2)
cos(tag1,alljets)$_{\text{alljets}}$	M_T(W)
cos(tag1,lepton)$_{\text{btaggedtop}}$	Missing E_T
cos(jet1,alljets)$_{\text{alljets}}$	p_T(alljets$-$best1)
cos(jet1,lepton)$_{\text{btaggedtop}}$	p_T(alljets$-$tag1)
cos(jet2,alljets)$_{\text{alljets}}$	p_T(jet1,jet2)
cos(jet2,lepton)$_{\text{btaggedtop}}$	Q(lepton)$\times\eta$(untag1)
cos(lepton,Q(lepton)$\times z$)$_{\text{besttop}}$	$\sqrt{\hat{s}}$
cos(lepton$_{\text{besttop}}$,besttop$_{\text{CMframe}}$)	Sphericity(alljets,W)
cos(lepton$_{\text{btaggedtop}}$,btaggedtop$_{\text{CMframe}}$)	
cos(notbest,alljets)$_{\text{alljets}}$	
cos(notbest,lepton)$_{\text{besttop}}$	
cos(untag1,alljets)$_{\text{alljets}}$	
cos(untag1,lepton)$_{\text{btaggedtop}}$	

For angular variables, the subscript indicates the reference frame.

Single Top CDF

Process	Number of Events in 1.51 fb^{-1}
s-channel	23.9±5.4
t-channel	37.0±9.3
$Wb\bar{b}$	319.6±112.3
$Wc\bar{c}, Wcj$	324.2±115.8
$Mistags$	214.6±27.3
$t\bar{t}$	85.3±17.3
$\mathrm{Diboson}/Z+jets$	54.5±6.0
$non-W$	44.5±17.8
Total signal	60.9±15.3
Total background	1042.8±218.2
Total prediction	1103.7±230.9
Observed in data	1078



W+2jets bin
(≥1 bjet)

Single Top CDF LF

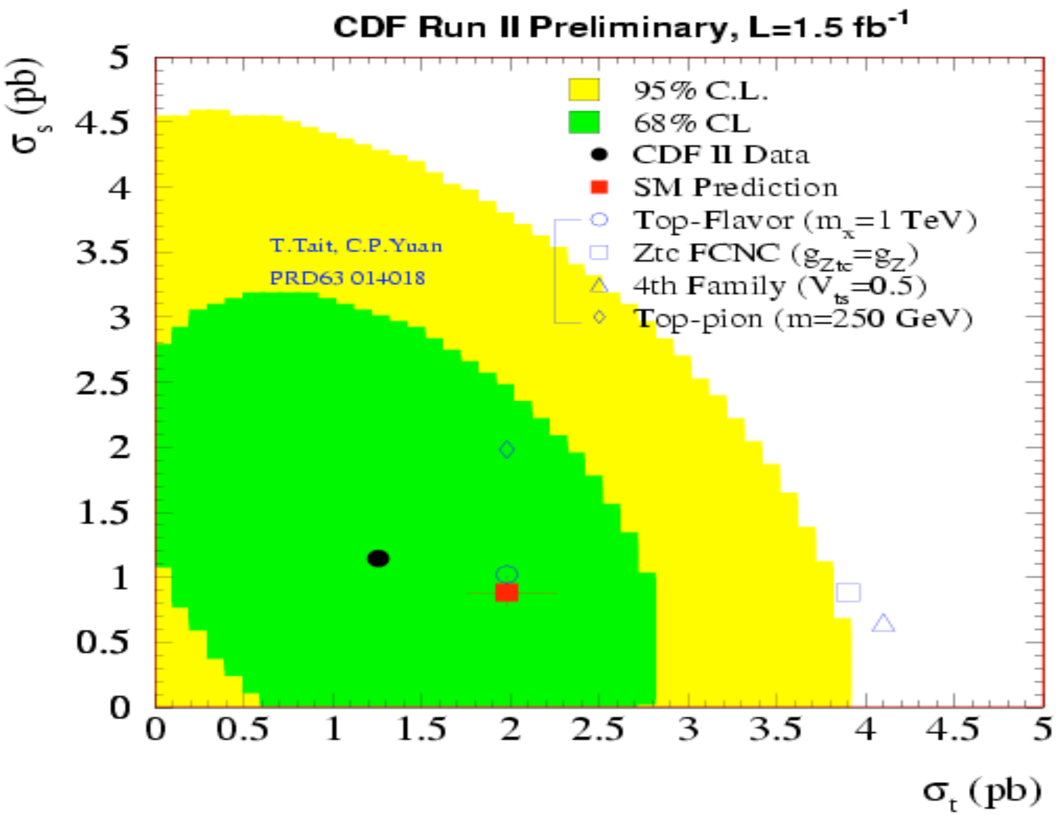


FIG. 7: The best fit value for σ_s and σ_t obtained from fitting the 2-dimensional $\mathcal{L}_s$ vs. $\mathcal{L}_t$ distribution. A $\Delta\chi^2$ is computed, comparing the $\chi^2(\sigma_s, \sigma_t)$ against that of best-fit corresponding to (σ_s, σ_t) = (0.1 pb, 0.2 pb). The 1σ fit region and the region allowed at the 95% C.L. are shown, along with the Standard Model prediction.

Single Top CDF ME

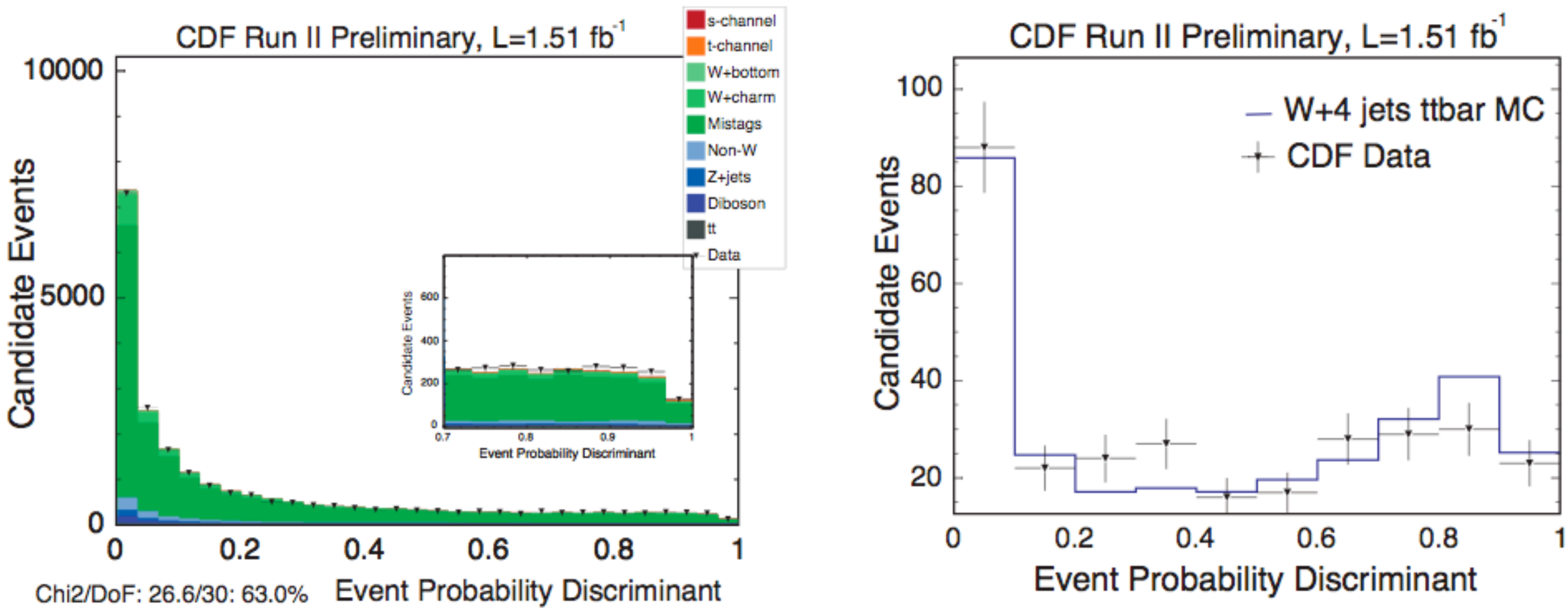


FIG. 3: Left: Evaluation of the event probability discriminant in the high statistics taggable but untagged $W + 2$ jets control sample. The hatched band accounts for the Monte Carlo statistical uncertainty. The error bars on the data points are Gaussian errors. Right: Evaluation of the event probability discriminant in the tagged $W + 4$ jets sample using only the two jets with the highest transverse momentum as input to the discriminant calculation. This control sample is enriched in $t\bar{t}$ events ($\sim$ 85%).

Single Top CDF ME

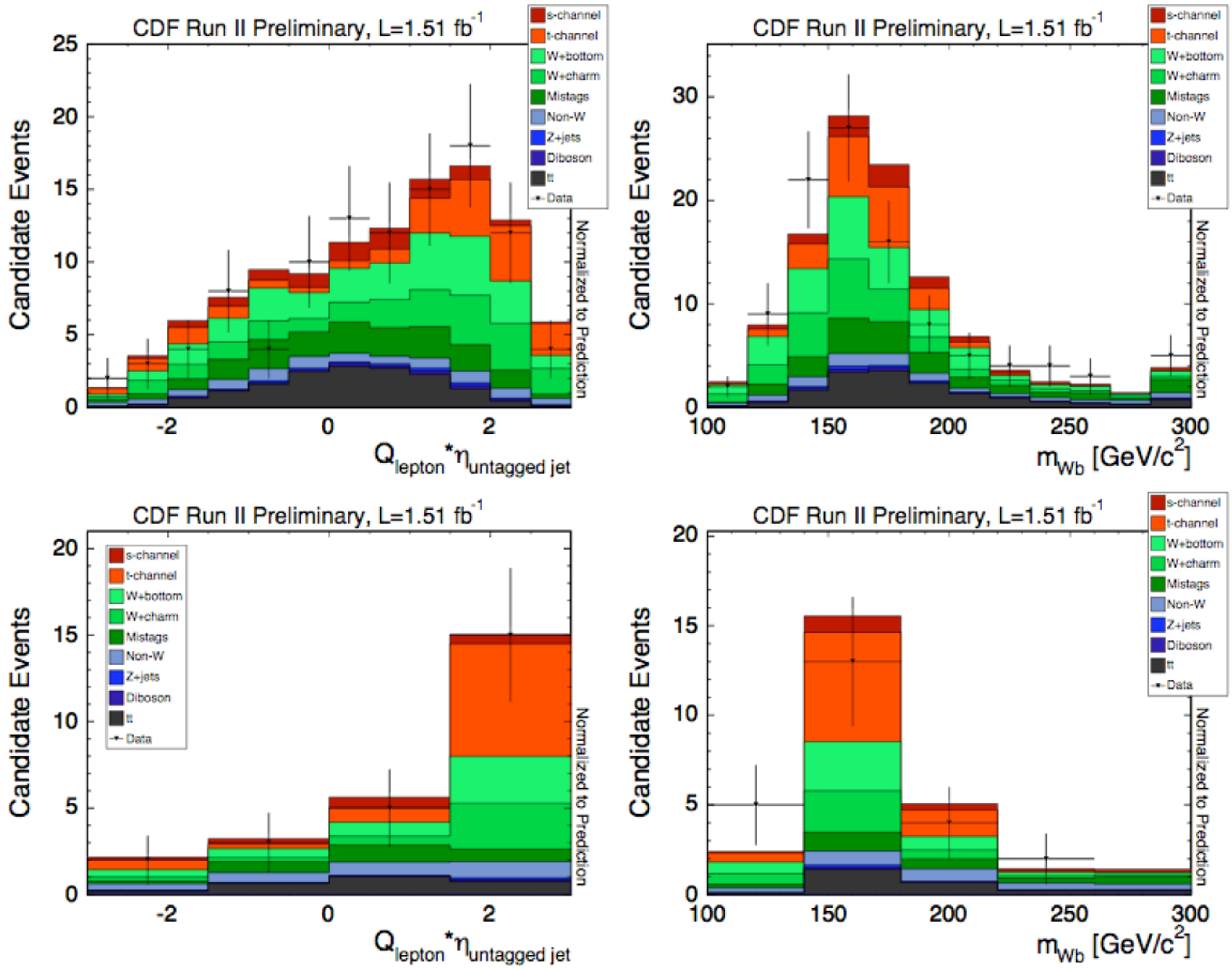
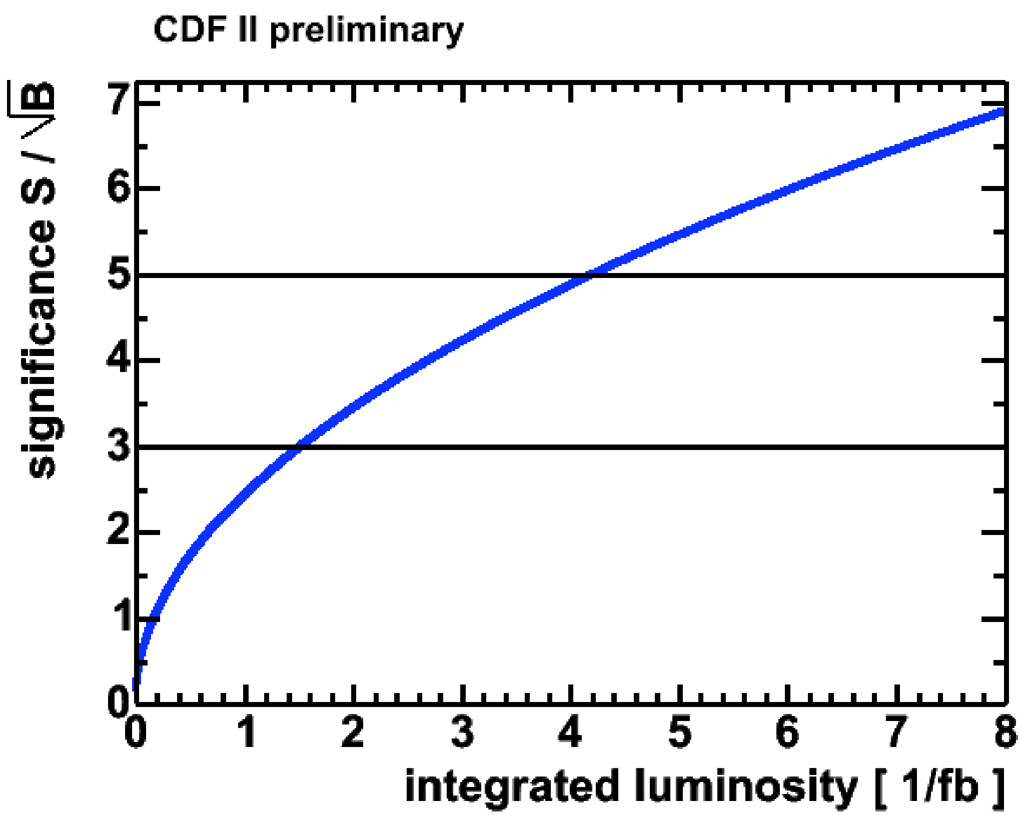
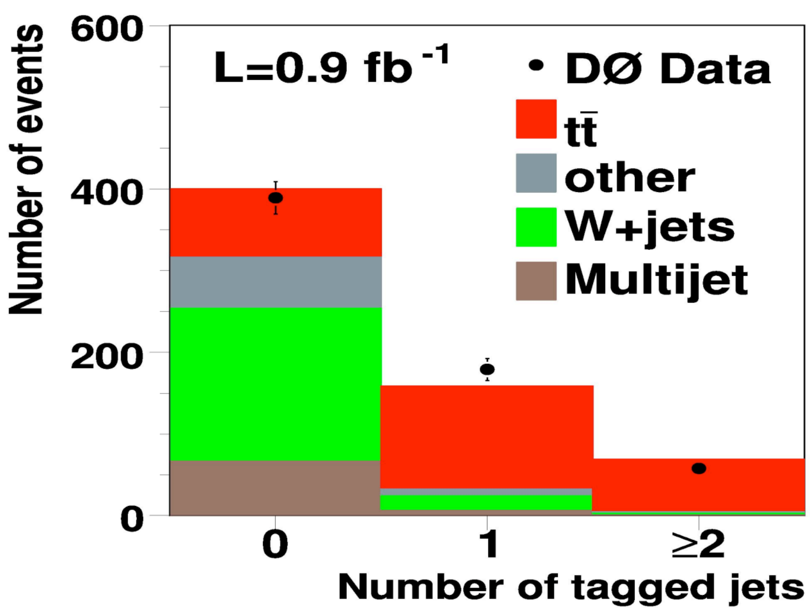


FIG. 9: Data and Monte Carlo comparison of the $Q_{lepton} \cdot \eta_{untagged\ jet}$ and m_{Wb} distributions for increasing cuts on the EPD discriminant. The top row includes the last three bins of the EPD discriminant (EPD>0.9) and the bottom row includes the last bin of the EPD discriminant (EPD>0.966).

Projections for Single Top Sensitivity



σ_{ttbar} and R



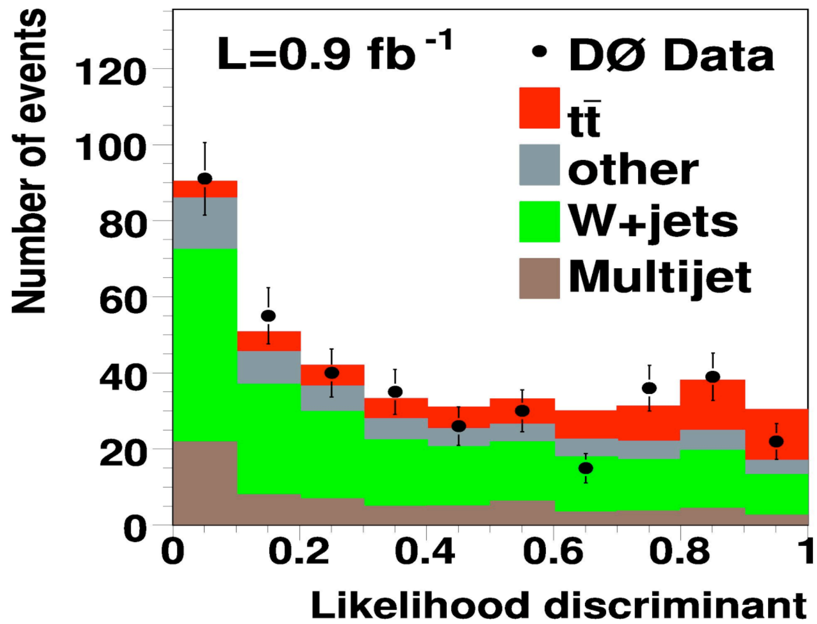
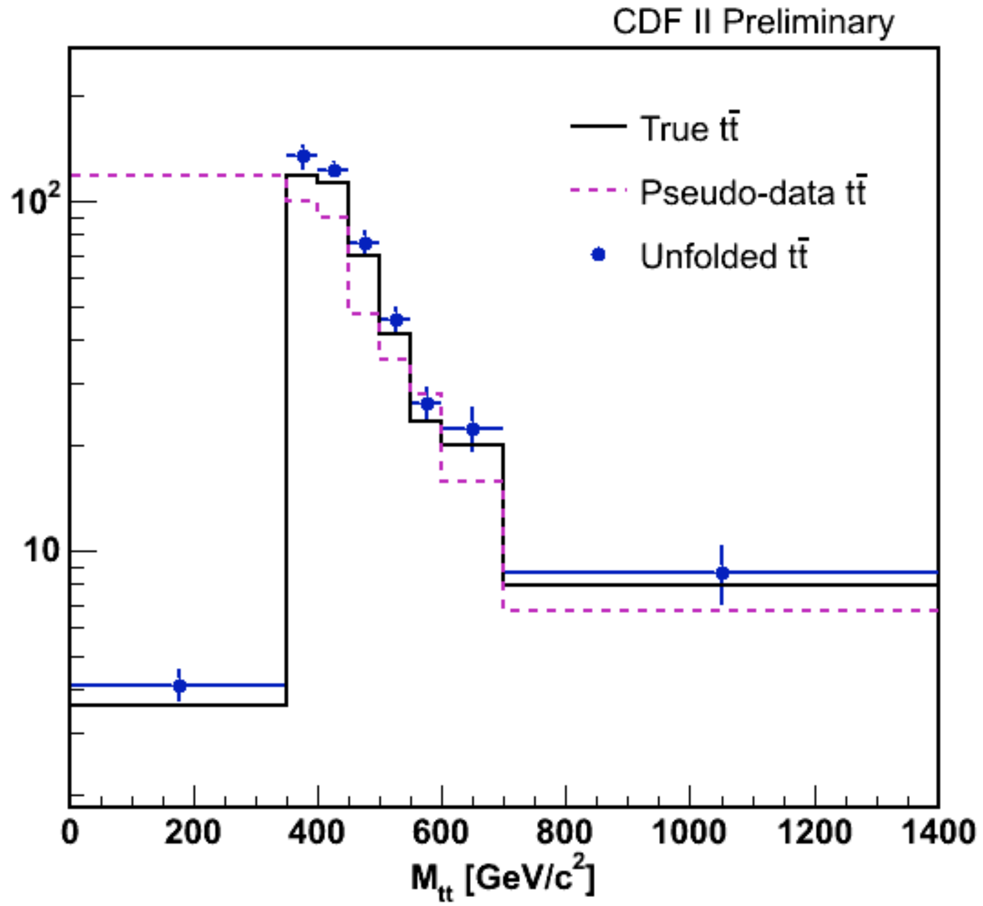


TABLE II: Summary of uncertainties on $\sigma_{t\bar{t}}$ and R.

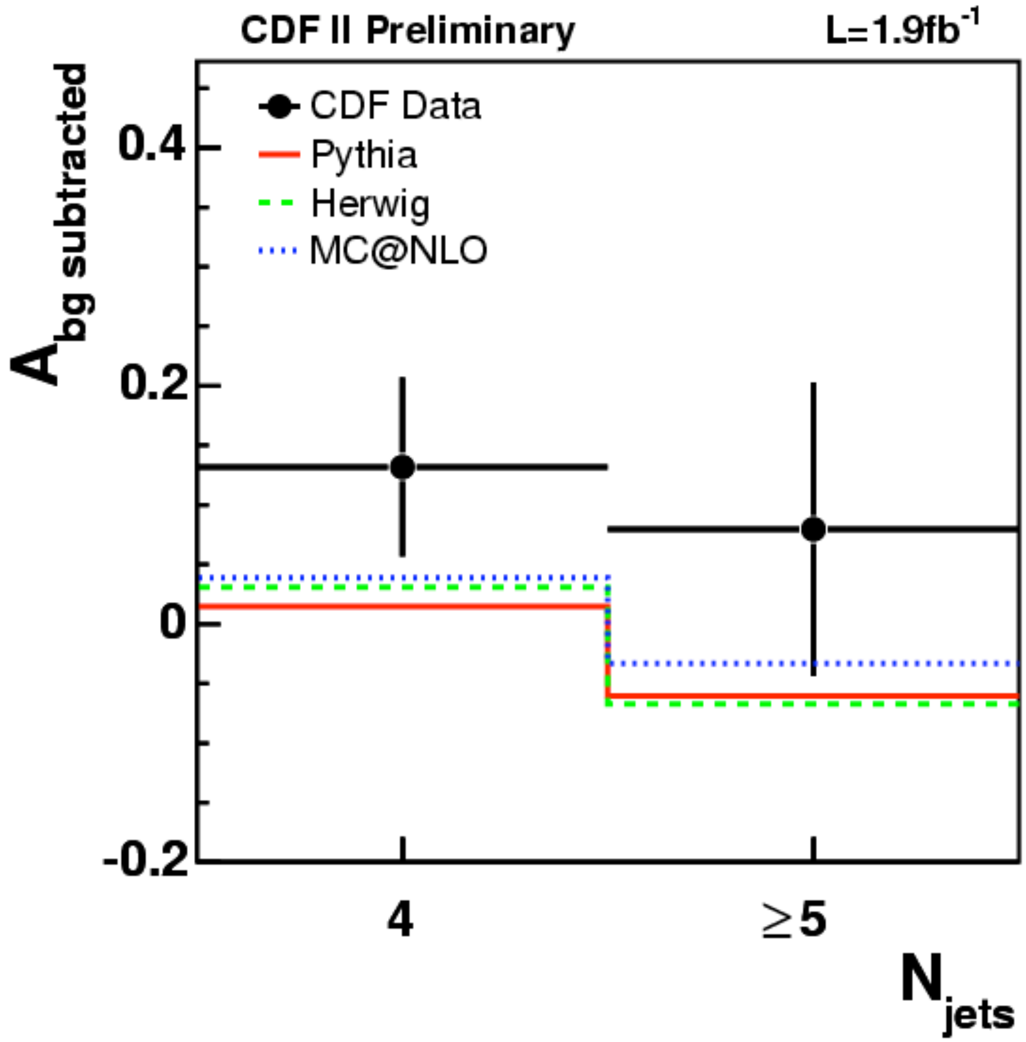
Source	$\Delta\sigma_{t\bar{t}}$ (pb)	ΔR
Statistical	+0.67 −0.64	+0.067 −0.065
Lepton identification	+0.32 −0.27	n/a
Jet energy scale	+0.32 −0.23	n/a
W+jets background	+0.21 −0.23	n/a
Multijet background	+0.17 −0.17	+0.016 −0.016
Signal modeling	+0.12 −0.25	n/a
b-tagging efficiency	+0.10 −0.09	+0.059 −0.047
Other	+0.24 −0.13	+0.015 −0.014
Total uncertainty	+0.90 −0.84	+0.092 −0.083

$D\sigma/dM_{ttbar}$

An example unfolded Mttbar distribution compared with the true and a simulated measured distribution.



A_{FB} CDF



CDF II Preliminary
L=1.9fb-1
CDF Data
Pythia
Herwig
MC@NLO
A bg subtracted
0.4
0.2
0
-0.2
4
≥5
N jets

Massive Gluon

The top quark is the heaviest elementary particle, which could be sensitive to the physics beyond standard model [1]. The search for the new color-singlet particle decaying the top pair have been performed at both CDF and DØ [2, 3]. In this analysis we search for the new color-octet particle, *"massive gluon (G)"*, based on the generic assumption. The top quark pairs are produced coherently in $q\bar{q}$ annihilation process in this case. The production matrix element can be written as,

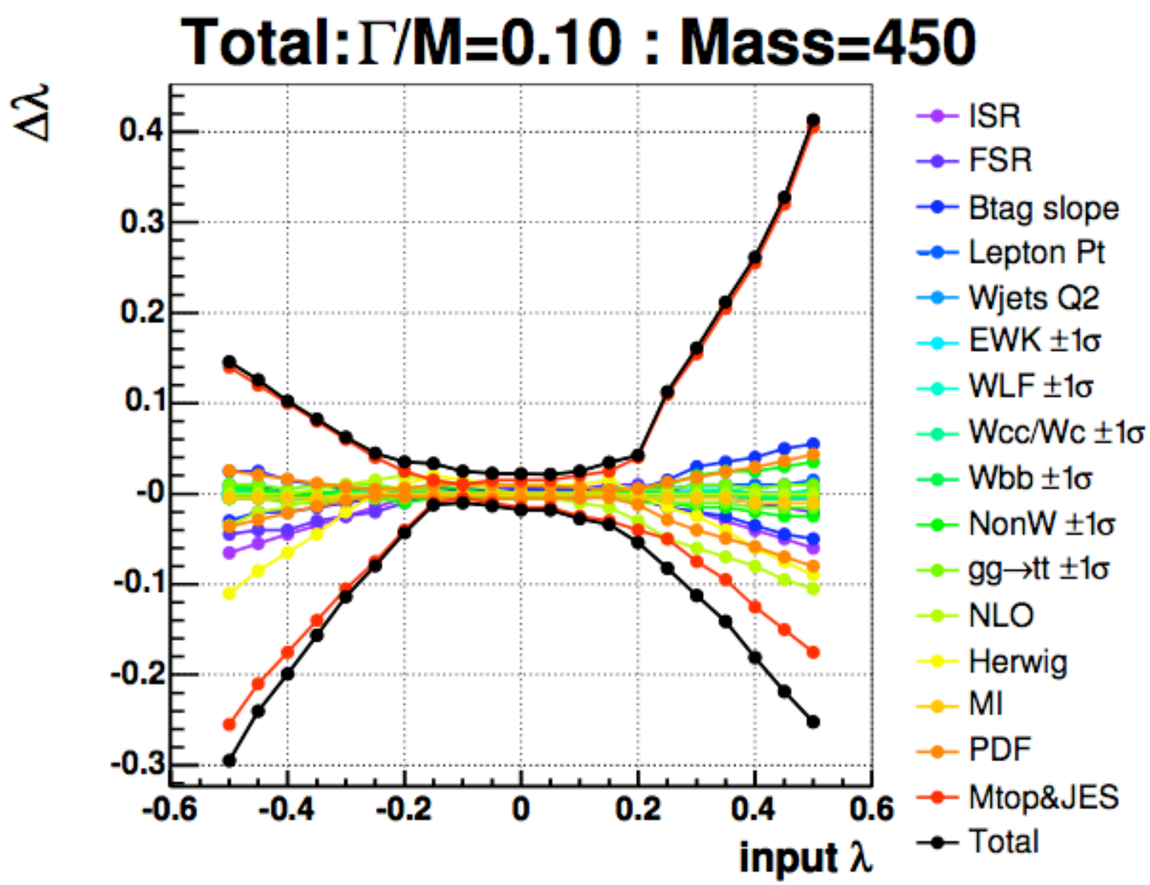
$$|\mathcal{M}_{\mathrm{prod.}}|^2 = \frac{9}{2} g_s^4 \hat{s}^2 (2 - \beta^2 + \beta^2 \cos^2\theta)(\Pi_g + \lambda \Pi_{\mathrm{int.}} + \lambda^2 \Pi_G) \quad (1)$$

where the propagator factors are

$$\Pi_g = \frac{1}{\hat{s}^2}, \ \Pi_G = \frac{1}{(\hat{s} - M^2)^2 + M^2\Gamma^2}, \ \Pi_{\mathrm{int.}} = \frac{2}{\hat{s}} \frac{\hat{s} - M^2}{(\hat{s} - M^2)^2 + M^2\Gamma^2} \quad (2)$$

$\lambda \equiv \lambda_q \lambda_Q$. λ_q and λ_Q are the coupling strength of massive gluon to the light quark and heavy quark, relative to the strong coupling as shown in the figure1. There are 3 modeling parameters, λ (strength of coupling), mass, and the decay width. λ can be both positive and negative. We assume no parity violation.

Massive Gluon



Example of systematics

W'

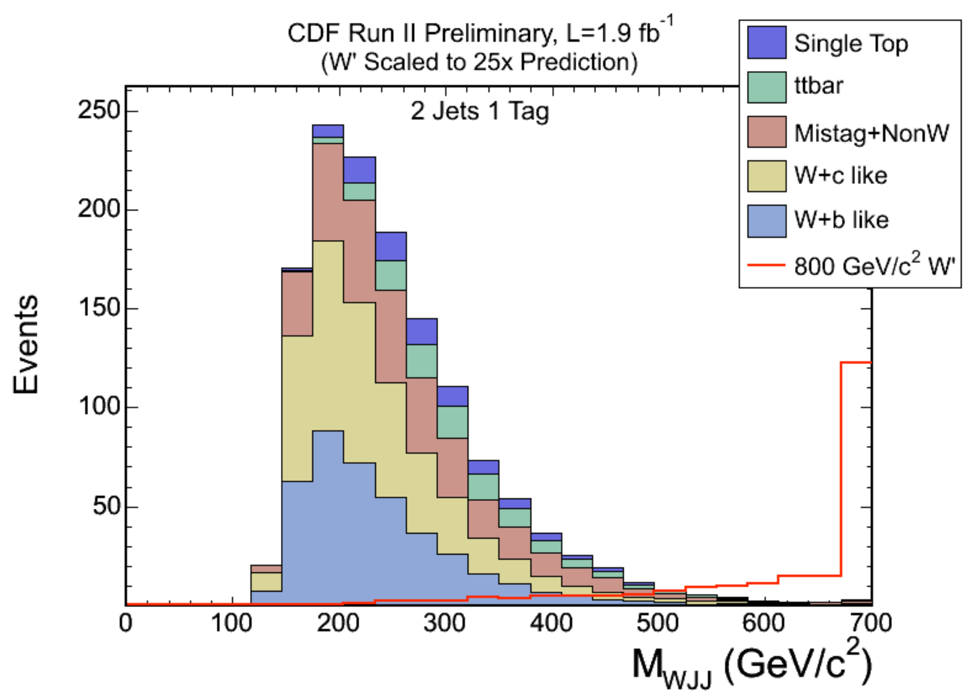
IV. W' SIGNAL

A. R and L-Handed W' Models

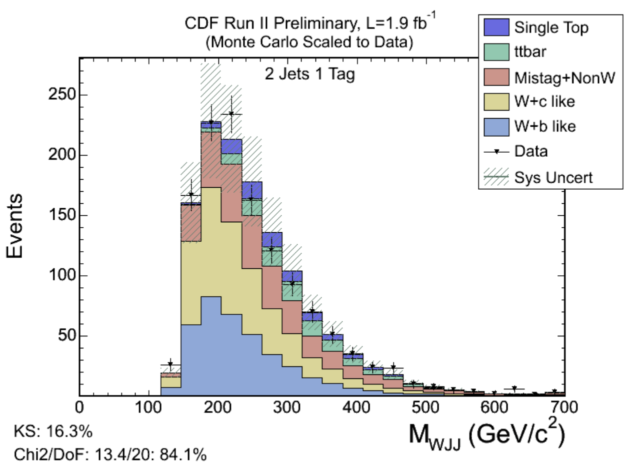
The Lagrangian describing the W' coupling to fermions can be written as [9]:

$$\mathcal{L} = g\bar{f}_i\gamma_\mu(C^R_{ij}P_R + C^L_{ij}P_L)W'f_j \qquad (1)$$

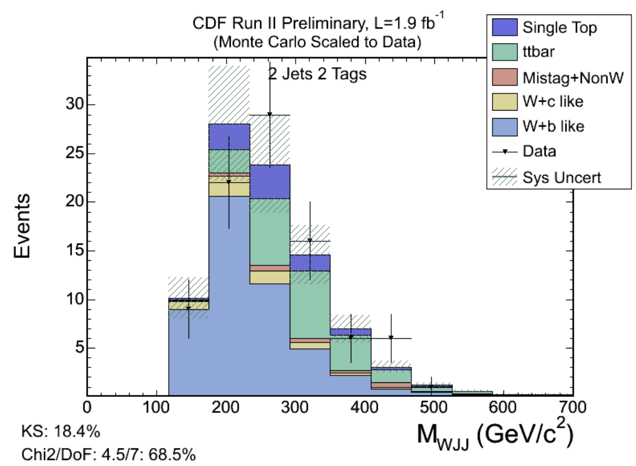
where $P_{L,R} = (1 \pm \gamma_5)/2$ are the projection operators, g is the gauge coupling, and the $C^{L,R}_{ij}$ are arbitrary coupling that differ for quarks and leptons. We assume that the W' has purely right-handed or left-handed couplings. Figure 2 shows the dominant s-channel diagram for W' production. Contributions from the $t-$ and $u-$ channels are suppressed by the large W' mass.



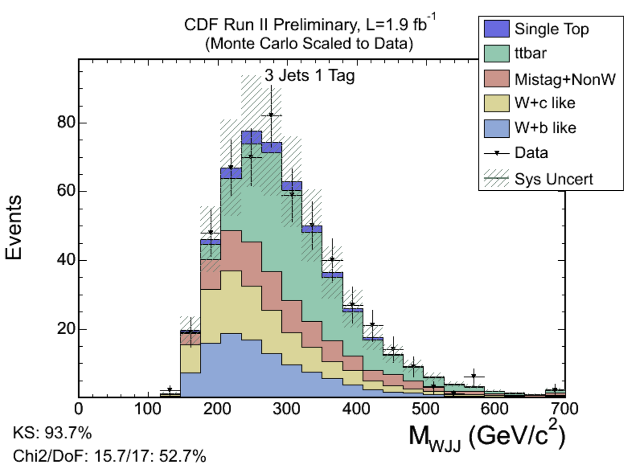
W'



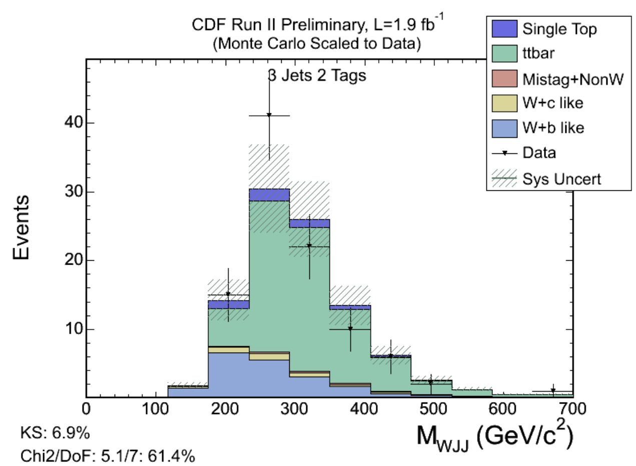
CDF Run II Preliminary, L=1.9 fb^{-1}
(Monte Carlo Scaled to Data)
2 Jets 1 Tag
Single Top
ttbar
Mistag+NonW
W+c like
W+b like
Data
Sys Uncert
Events
M_{WJJ} (GeV/c^2)
KS: 16.3%
Chi2/DoF: 13.4/20: 84.1%



CDF Run II Preliminary, L=1.9 fb^{-1}
(Monte Carlo Scaled to Data)
2 Jets 2 Tags
Single Top
ttbar
Mistag+NonW
W+c like
W+b like
Data
Sys Uncert
Events
M_{WJJ} (GeV/c^2)
KS: 18.4%
Chi2/DoF: 4.5/7: 68.5%



CDF Run II Preliminary, L=1.9 fb^{-1}
(Monte Carlo Scaled to Data)
3 Jets 1 Tag
Single Top
ttbar
Mistag+NonW
W+c like
W+b like
Data
Sys Uncert
Events
M_{WJJ} (GeV/c^2)
KS: 93.7%
Chi2/DoF: 15.7/17: 52.7%

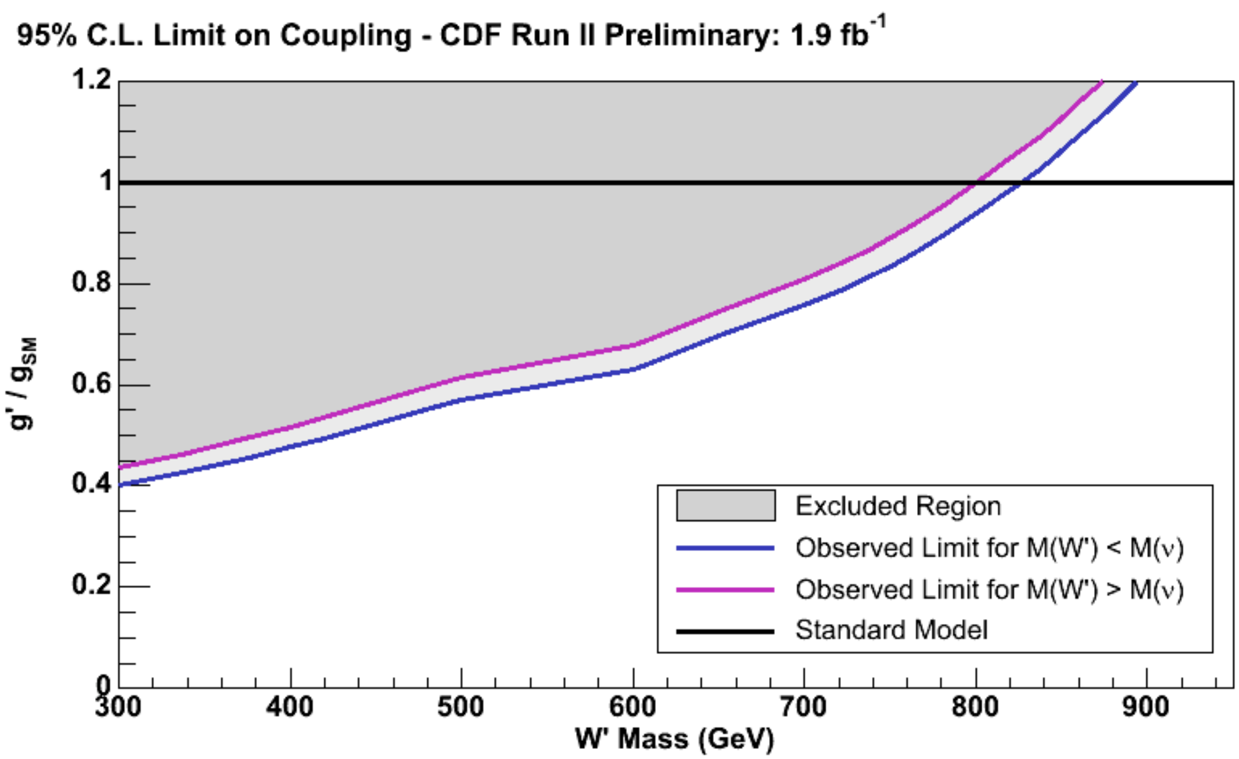


CDF Run II Preliminary, L=1.9 fb^{-1}
(Monte Carlo Scaled to Data)
3 Jets 2 Tags
Single Top
ttbar
Mistag+NonW
W+c like
W+b like
Data
Sys Uncert
Events
M_{WJJ} (GeV/c^2)
KS: 6.9%
Chi2/DoF: 5.1/7: 61.4%

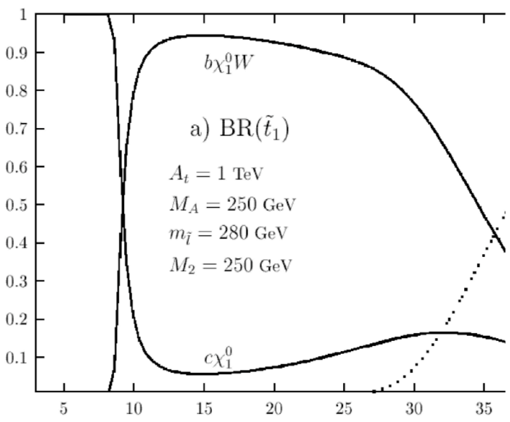
W' Coupling Limits

For a given mass $M_{W'}$ we can adjust g until the cross-section of the model calculated via scaling by g^4/g^4_{SM} equals the experimentally excluded cross-section. This is precisely how the $M_{W'}-g$ graph is constructed.

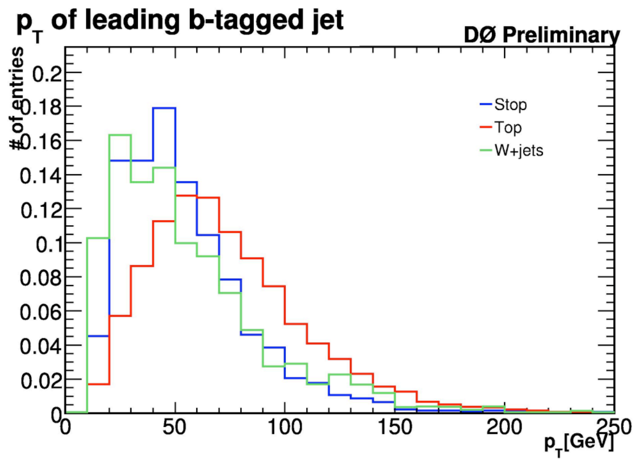
We exclude gauge couplings down to $0.4g_{SM}$ for low W' masses and $M_{W'}<M(\nu)$.



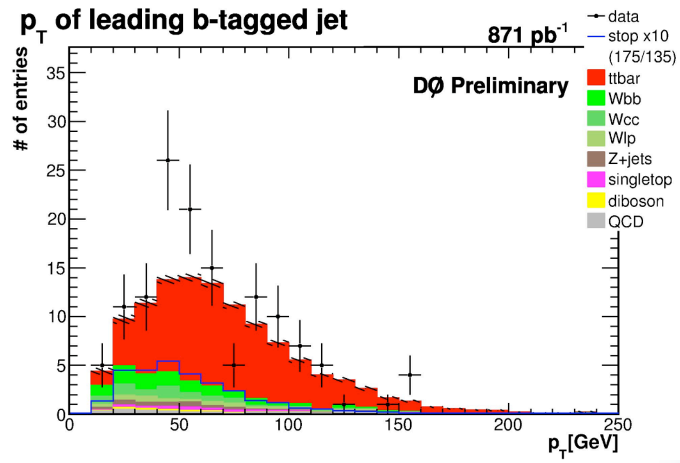
Scalar Top



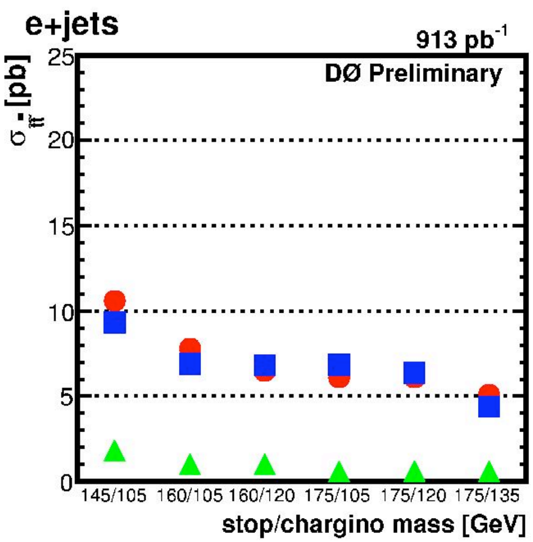
a) $BR(\tilde{t}_1)$
$b\chi_1^0 W$
$c\chi_1^0$
$A_t = 1$ TeV
$M_A = 250$ GeV
$m_{\tilde{l}} = 280$ GeV
$M_2 = 250$ GeV



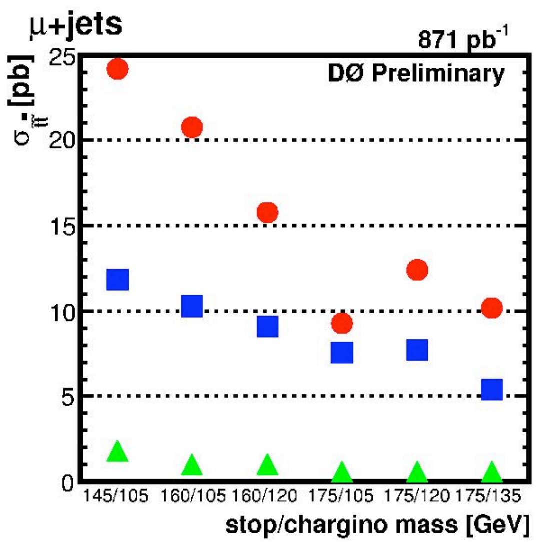
p_T of leading b-tagged jet
DØ Preliminary
# of entries
Stop
Top
W+jets
p_T[GeV]



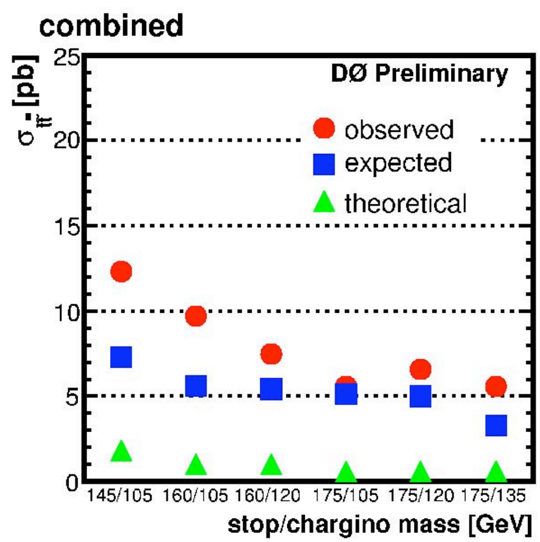
p_T of leading b-tagged jet
871 pb^{-1}
DØ Preliminary
# of entries
data
stop x10 (175/135)
ttbar
Wbb
Wcc
Wlp
Z+jets
singletop
diboson
QCD
p_T[GeV]



e+jets
913 pb^{-1}
DØ Preliminary
$\sigma_{t\bar{t}}$ [pb]
145/105
160/105
160/120
175/105
175/120
175/135
stop/chargino mass [GeV]



μ+jets
871 pb^{-1}
DØ Preliminary
$\sigma_{t\bar{t}}$ [pb]
145/105
160/105
160/120
175/105
175/120
175/135
stop/chargino mass [GeV]



combined
DØ Preliminary
observed
expected
theoretical
$\sigma_{t\bar{t}}$ [pb]
145/105
160/105
160/120
175/105
175/120
175/135
stop/chargino mass [GeV]

Scalar Top

III. MONTE CARLO SIMULATION

The $\tilde{t}_1\bar{\tilde{t}}_1$ signal events in the lepton+jets topology were generated using PYTHIA v6.323 [13] in its general MSSM mode. The neutralino $\tilde{\chi}_1^0$ is the LSP and the MSSM parameters are chosen as follows:

- $\tan\beta = 20$, $\mu = 225$ GeV, $M_A = 800$ GeV, $M_1 = 53$ GeV, $M_3 = 500$ GeV,
- Trilinear couplings $A_b = A_\tau = 200$ GeV,
- Scalar lepton masses $M_{\tilde{l}_L} = M_{\tilde{l}_R} = M_{\tilde{\tau}_L} = M_{\tilde{\tau}_R} = 200$ GeV,
- Scalar quark masses $M_{\tilde{q}_L} = M_{\tilde{q}_R} = M_{\tilde{b}_R} = M_{\tilde{t}_R} = 250$ GeV.

For this set of SUSY parameters the branching ratio for $\tilde{t}_1 \to \tilde{\chi}_1^+ b$ is 100% according to PYTHIA. The masses of the stop quark, the lightest chargino, and the lightest neutralino are determined essentially by the top trilinear coupling A_t and the gaugino masses M_2 and M_1, respectively. These were chosen to produce the specific mass points given in Table I. The table also shows the corresponding cross section for $\tilde{t}_1\bar{\tilde{t}}_1$ production for each mass point as calculated in PROSPINO. The mass difference between the chargino and the neutralino determines if the chargino will decay to a neutralino and a real W boson or to a neutralino and a lepton with a neutrino or quarks via a virtual W boson. For the produced mass points a real W boson is only possible for the mass point with a chargino mass of 135 GeV (and a stop quark mass of 175 GeV).

Mass point	$\sigma_{\tilde{t}_1\bar{\tilde{t}}_1}$	A_t	$m_{\tilde{t}_1}$	M_2	$m_{\tilde{\chi}_1^\pm}$	M_1	$m_{\tilde{\chi}_1^0}$
Stop 175/135	0.579 pb	357 GeV	175 GeV	164 GeV	135 GeV	53 GeV	50 GeV
Stop 175/120	0.579 pb	357 GeV	175 GeV	144 GeV	120 GeV	53 GeV	50 GeV
Stop 175/105	0.579 pb	357 GeV	175 GeV	125 GeV	105 GeV	53 GeV	50 GeV
Stop 160/120	1.00 pb	387 GeV	160 GeV	144 GeV	120 GeV	53 GeV	50 GeV
Stop 160/105	1.00 pb	387 GeV	160 GeV	125 GeV	105 GeV	53 GeV	50 GeV
Stop 145/105	1.80 pb	414 GeV	146 GeV	125 GeV	105 GeV	53 GeV	50 GeV

Table I: Stop/Chargino mass points used in this analysis with their $\tilde{t}_1\bar{\tilde{t}}_1$ cross section, SUSY parameters and particle masses.